

23 MAY 1991



# ***JPRS Report***

# **Science & Technology**

***USSR: Earth Sciences***

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# Science & Technology

## USSR: Earth Sciences

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**Experience in Using STsS-3 Data Processing System for Interpreting Multichannel Seismic Records Registered on Shelf of Antarctic Seas**

*917N0085A Leningrad INFORMATSIONNY BYULLEHEN SOVETSKOY ANTARKTICHESKOY EKSPEDITSII in Russian No 113, 1990 pp 24-35*

[Article by V. V. Butsenko and G. A. Kudryavtsev, Northern Production Association for Marine Geological Prospecting Work (Sevmorgeologiya Geological Production Association)]

[Abstract] Seismic research by the reflected waves-common depth point method was carried out on the shelf of the Sea of Cooperation (Antarctic Ocean) during the 32d Soviet Antarctic Expedition. The results (supplemented by materials collected by other Soviet and foreign expeditions) were used in an attempt at study of the entire thickness of the sedimentary layer. The great difficulties involved in such processing are discussed. The STsS-3 data processing system was used for this purpose. It is emphasized that the integrity of the computer processing procedures described in the article was compromised the low quality of the input data (attributable to the influence of unfavorable seismogeological and hydrometeorological conditions in the observation region). A number of special programs (RECON, REFIL, VELAN) were used in the processing; the merits and deficiencies of each is evaluated. The programs and procedures were effective to various degrees in filtering out a number of types of interference and in interpreting the complex wave pattern, but any increase in the effective depth and accuracy of the method can be

achieved only with improvements in field observation methods. Figures 4; references 7: 4 Russian, 3 Western.

**Integral Transparency and Aerosol Optical Depth of Atmosphere at Mirnyy Observatory**

*917N0085B Leningrad INFORMATSIONNY BYULLEHEN SOVETSKOY ANTARKTICHESKOY EKSPEDITSII in Russian No 113, 1990 pp 48-51*

[Article by V. F. Radionov, Arctic and Antarctic Scientific Research Institute]

[Abstract] The integral transparency coefficient  $P_2$  and aerosol optical depth of the atmosphere at 500 nm ( $\tau_{500}$ ) at Mirnyy Observatory in Antarctica were investigated as parameters characterizing the optical state of the atmosphere. The mean monthly  $P_2$  and  $\tau_{500}$  values registered at Mirnyy since 1980 indicated that they have a seasonal variation. The  $\tau_{500}$  values increase from winter to summer, attain a maximum in December-January and then decrease. The summer  $\tau_{500}$  values exceed the spring and autumn values. The mean monthly  $P_2$  values are registered in summer. The seasonal changes in the integral transparency coefficient are attributable not only to the moisture content, but also aerosol turbidity. The year-to-year  $P_2$  and  $\tau_{500}$  variations are also quite great. During the period 1979-1987 a sharp change began in November 1982. The maximal  $\tau_{500}$  value was in January 1983, greater by a factor of 3.6 than the level for January 1981. With an increase in  $\tau_{500}$  there was a  $P_2$  decrease. In Antarctica there was a decrease in atmospheric transparency in November 1982, seven months after eruption of El Chichon volcano, a decrease which persisted for three and a half years. Figure 1; references: 5 Russian.

**Atmospheric Glow Response to Spitak Earthquake of 7 December 1988**

917N0083A *Tbilisi OTKLIK SVECHENIYA ATMOSFERY NA ZEMLETRYASENIYE V SPITAKE 7 XII 1988 g. in Russian 1990 pp 1-11*

[Article by G. G. Didebulidze, T. I. Toroshelidze and S. P. Chilingarashvili, Abastumani Astrophysical Observatory, Georgian Academy of Sciences]

[Abstract] A response of the ionospheric F region to a number of earthquakes has been observed. Disturbances of the geomagnetic field and ionosphere also were registered during the Spitak earthquake of 7 December 1988. In the F region there was an anomalous increase in electron concentration and an intensification of wave (with a period three-120 minutes) activity. Prior to the Spitak earthquake atmospheric glow had been observed at Abastumani only in October 1988. After the main Spitak tremor this glow began on the night of 7-8

December, 10 hours after the event, and also on the night of 9-10 December. Variations in the intensities of emission at 630 nm and in the hydroxyl band (6.2) were investigated in the spectral region 835 nm using three- and four- azimuth electrophotometers with intervals between readings one and a half and two minutes in each direction at an angle 45° to the horizon. The studied period was characterized by extremely low geomagnetic activity, precluding any 630 nm emission behavior attributable to magnetic field variations. The existence of a meridional component of wind speed at F-layer altitudes was a highly significant factor in the observed behavior. The altitude of the layer emitting the 630 nm emission descended from 260 to 220 km and there was a cascade process of energy transfer from the range of periods 10-six minutes to the range of periods more than 30 and less than five minutes. The various possible reasons for the earthquake-related behavior of both  $I_{630}$  and  $I_{OH}$  (6.2) are explored. Figures 3; references 14: 11 Russian, 3 Western.

### Simulating Effects of Atmospheric Nuclear Shots on Stratospheric Ozone Content

917N0071A Moscow METEOROLOGIYA I  
GIDROLOGIYA in Russian No 12, Dec 90 (manuscript received 15 Jun 90 pp 5-15)

[Article by Yu. A. Izrael, corresponding member, USSR Academy of Sciences, V. N. Petrov, doctor of physical and mathematical sciences, D. A. Severov, candidate of physical and mathematical sciences, and R. M. Fatakhed-dinov, Applied Geophysics Institute, USSR State Committee for Hydrometeorology]

UDC [551.510.534:623.454.82].001.57

[Abstract] A study was made of the formation of atmospheric ozone under the influence of the UV radiation and radioactive emissions of the fireball of a nuclear shot, the contribution of this ozone increment to the total ozone balance, the change in ozone concentration in the ascending cloud of a nuclear shot, the influence exerted on the ozone content by (H + OH) forming as a result of dissociation of atmospheric water under the influence of the nuclear radiation of the fireball and the influence of change in stratospheric temperature caused by dust injection into the stratosphere. Photochemical reactions in the shot cloud and diffusional expansion of the shot cloud occurring during its ascent and after stabilization are examined. Both individual cases and massed shots, as in a nuclear war scenario (up to 10 000 Mt), are considered. An attempt is made to evaluate the change in content of stratospheric ozone from the injection of nitrogen oxides and dust from such a massed series of nuclear shots by calculations of heating of the stratosphere by shot-induced dust and natural atmospheric self-purification. Figures 4; references 17: 7 Russian, 10 Western.

### Trajectory Model of Transport of Pollutants

917N0071B Moscow METEOROLOGIYA I  
GIDROLOGIYA in Russian No 12, Dec 90 (manuscript received 22 Mar 90) pp 67-74

[Article by P. N. Belov, professor, and Z. L. Karlova, Moscow State University]

UDC 504.3.054.001.572(47)

[Abstract] A trajectory model is proposed which makes it possible to trace the atmospheric propagation of any substance. As an example of application of the model a study was made of the transport of sulfur dioxide in the lower layer of the atmosphere from the Earth's surface to an altitude of about 1.5 km (isobaric surface 850 gPa). This model differs from earlier known models of transport of a substance for the most part with respect to the method for computing the trajectories of an air volume, the method for integrating the equation for transport along a trajectory, the method for taking into account the

change in wind with altitude and allowance for small- and medium-scale turbulence. Application of the model is illustrated by observations in the European USSR with computations of the 24-hour change in the concentration and dry precipitation of SO<sub>2</sub>. Computations were made with two-hour time intervals for one day, 10 February 1989, at a time when there was a well-developed anticyclone over the greater part of the computation region. In this case the transport of pollutants was mostly along the eastern periphery of the anticyclone. In cases when there is virtually no transport of pollutant the regions in which the sources of effluent are situated pollute themselves. Sometimes certain source areas, despite strong transport of pollutants away from local effluent sources, have very high pollution due to receipts of pollutants from other regions. Figures 3; references 14: 10 Russian, 4 Western.

### Correlation Between Regions of Anomalously Low Ozone Content and Baric Situation

917N0071C Moscow METEOROLOGIYA I  
GIDROLOGIYA in Russian No 12, Dec 90 (manuscript received 19 Sep 89) pp 103-105

[Article by V. I. Bekoryukov and G. R. Zakharov, candidates of physical and mathematical sciences, A. A. Kukoleva and V. E. Fioletov, Central Aerological Observatory]

UDC 551.510.534:551.547.5

[Abstract] A study was made of regions of anomalously low ozone content in the middle latitudes, giving particular attention to the observed decrease in ozone content in places with a stratospheric circumpolar cyclone during autumn-winter, as well as in places where there is a stratospheric ridge with an inflow of tropical air masses. The study was made in a number of situations (over western Europe, Scandinavia, the northwestern European USSR and northeastern Canada, and also in the Iceland-Scandinavia region). In all cases there was a well-developed ridge in the lower stratosphere; in the first four cases the pressure field was zonal; in the last two cases, in which the ozone decrease was strongest in comparison with its climatic value, there was a stratospheric circumpolar cyclone in the mentioned regions. The regions of minimal total ozone content values were accompanied by regions of low temperatures in the middle stratosphere, probably caused by adiabatic cooling by ascending currents. The dynamic mechanisms leading to the observed ozone decreases are examined in detail in the example of the first case. For example, vertical currents were computed in the layer 300-10 gPa on the basis of a system of equations in hydrodynamics and using pressure pattern charts. The region of ascending currents virtually coincided with the region of minimal total ozone content. Ascending currents with a velocity 2 cm/s resulted in a decrease in total ozone content by approximately 5 percent per day. The results of vertical current computations also revealed the nature of the correlation between different atmospheric layers because ascending currents in the middle stratosphere can be caused only by the pressure situation in the upper troposphere and lower stratosphere. Figures 2; references: 3 Russian.

**Aboard the "Akademik Ioffe"**

917N0107A Moscow *PRIRODA* in Russian No 1,  
Jan 91 pp 47-51

[Article by Doctor of Physicomathematical Sciences Yu. Yu. Zhitkovskiy, Candidate of Geological-Mineralogical Sciences N. S. Skornyakova, A. Yu. Zakhlestin and N. Yu. Terskiy, Oceanology Institute imeni P. P. Shirshov, USSR Academy of Sciences, Moscow]

[Text] In February 1989 we came aboard a new scientific research vessel, the "Akademik Ioffe," built for the USSR Academy of Sciences in the Finnish city of Rauma, at the building dock of the Khollming [transliteration] joint-stock association. This first cruise of the vessel, which is intended for comprehensive ocean research and outfitted with the latest apparatus making it possible to replace traditional, extremely laborious oceanological methods by quick methods, was to be an "acoustic" cruise. Sound waves were to be used to study the ocean water column, icebergs, the ocean floor, and in particular, iron-manganese nodules in the North Atlantic. Their acoustic detection was the main objective of our integrated group, consisting of acoustics specialists and geologists.

Both the "Akademik Ioffe" and its sister ship "Sergey Vavilov" were designed by the Finns jointly with Soviet specialists from the USSR Academy of Sciences, and particularly from the Oceanological Institute. These comfortable diesel-powered vessels, which are capable of a speed of 15 knots, are 18 m wide and 117 m long, and they can travel a distance of 20,000 nautical miles without replenishing fuel and provisions. The vessel's navigation system calculates its precise coordinates and guides the vessel along a predetermined course (one or several). When adrift, the vessel can slowly change its position (in order to come nearer to another one) by means of rigid plastic sails—wind propellers.

The vessel carries a crew of 128, including research personnel. Besides the comfortable cabins, the vessels have a library and exercise rooms. There are around 20 permanent laboratories: meteorological, optical- radiometric, metrological, hydrological-hydrochemical, radiometric, data receiving and recording, geological and geophysical, and others. There is room for three interchangeable containerized laboratories that can be plugged in as necessary. In this case each laboratory has its own computers connected to measuring instruments and transmitting information to the vessel's common computer center.

Without going into the apparatus with which we worked during the cruise for the moment, we note that the vessel carries a sail- and motor-powered metrological boat connected to the vessel by a radiotelemetric data transmission system, which makes it possible for the boat to escape the vessel's noise field. Weak underwater acoustic signals are received during the vessel's "silent running," at which time a diesel generator operates in a special soundproofed cabin on the boat deck.

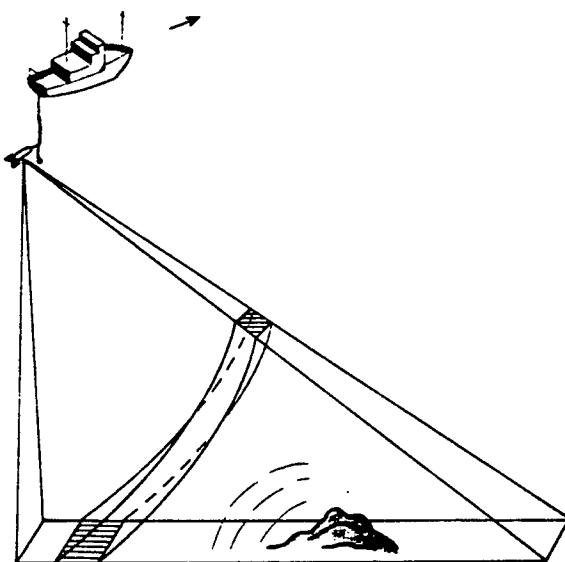
Fabulously equipped shops, photographic processing laboratories, winches, frames and cranes for research devices,

and various systems capable of descending to depths of several kilometers provide considerable support to the work.

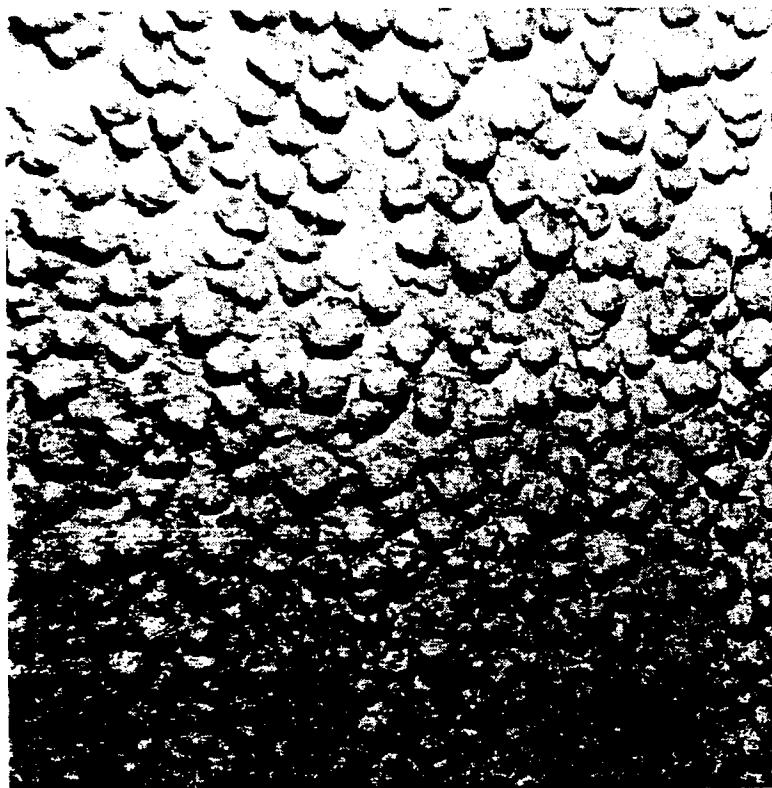
Now about the object of our research. Large reserves of manganese, nickel, copper, cobalt and other valuable metals contained in iron-manganese nodules widely scattered over the ocean floor have become an object of not only scientific but also economic interest. The bulk of them have been detected at depths of 4,000-6,000 m, where the nodules lie on the surface of sediments, and sometimes carpet the floor like cobblestones.

Bottom samplers, coring tubes, trawls and dredges have been used traditionally to find nodules and determine their concentration (percent coverage of the floor by them) and their quantity per unit area. Of these devices, only bottom samplers with a known sampling area are suitable for quantitative assessment, while the concentration of nodules is revealed more effectively by surveying the floor from a drifting vessel by the procedure of underwater photographic profile recording.

However, this kind of work is rather expensive, and it would be more preferable to carry it out after revealing the zones in which the concentration of iron-manganese nodules is the highest. Research conducted in recent years showed that nodules occur extremely nonuniformly over the surface of the floor. This is why it is much cheaper and simpler to explore them with photographic and television devices or acoustic instruments that are towed above the floor. But television devices, which are towed at a speed of 2-3 knots right at the very bottom, require intense illumination. The most effective acoustic instrument for mapping accumulations of iron-manganese nodules—side-looking sonar—is towed at the ocean surface (at a depth of 20-100 m) at a speed of 5-7 knots. In an hour of work, such an instrument surveys around 100 km<sup>2</sup> of the ocean floor.



Principle of Operation of Side-Looking Sonar



Nodule Pavement in the Brazil Basin

Side-looking sonar makes it possible to record sound scattering by the ocean floor, the level of which depends on the physical characteristics of sediments, rock or nodules covering the floor. Of course remote sensing of the floor does not make it possible to distinguish accumulations of nodules from placers of rock fragments of the same density, or a "nodule" pavement from a lava bed, and consequently geological correction—that is, rather frequent sampling—is required.

The sonar system emits an acoustic wave in a plane perpendicular to the towing direction. As it propagates, the sound first reaches the floor immediately beneath the sonar system, and it is reflected. Then scattering occurs from portions of the "sounded" ocean floor that are farther and farther away. Knowing the position of the sonar device and the time it takes an echo to travel from the floor, we can determine the location of the scattering area. Each area of the bottom is characterized by a certain signal scattering intensity. The next pulse "sounds" an adjacent strip of the floor, and so on. By recording the echoes, we arrive at a graphical image of the distribution of acoustic backscattering by the area of the bottom under investigation.

The side-looking sonar used in the cruise, SONAC LF, was developed jointly by the USSR Academy of Sciences and Finland's Khollming, and it is intended for surveying the floor at ocean depths down to 6,000 m. It can simultaneously survey a strip of floor up to 13-15 km

wide on both sides of the vessel's line of travel. The instrument has three working frequencies—5, 10 and 20 kHz—and separate receiving and emitting antennas, and in contrast to the best known long-range sonar system, the GLORIA, which requires a special vessel, it can be deployed by practically any kind of ship. The overall dimensions of this towed "fish" are 3.5x1.5x1.2 m, and its weight in air is around 500 kg. Owing to the use of frequency-modulated sensing signals the instrument has a wide scanning field at relatively low emitted power, which is why it has also come to be referred to as a "surveyor."

What we did in the first cruise of the "Akademik Ioffe" was to test the surveyor in a test area in the Brazil Basin and work out the methods of acoustic detection of nodules with its help. Such work had been done before with the surveyor in integration with geological survey, but this time we had at our disposal a multibeam echo sounder, which is used to study bottom relief, and a precision geographic tie-in system using navigation satellites made it possible to determine the vessel's location with a precision of 50 m.

The 60-beam ECHOS XD echo sounder surveys a strip twice as great as the depth beneath the keel,<sup>1</sup> but the most accurate information on bottom relief is received within a strip that is "one depth" wide. The survey was conducted for eight hours, considering that this was

precisely the time period over which satellite navigation "works." A bathymetric map of the test area, which covered around 400 km<sup>2</sup>, was ready in as little as 10 hours.

After sounding with the echo sounder was finished, 30 hours of work with the surveyor began. The distance between tacks (eight of them were made) was selected such that the images of the bottom would overlap. By the end of work at the test area, a procedure was developed for joint work of the multibeam echo sounder and the surveyor, which in the future will make it possible to simultaneously obtain, within 10 hours, both topographic data and a map of the intensity of sound scattered from the bottom—that is, the basis for geological mapping in a test area of 10x10 nautical miles.

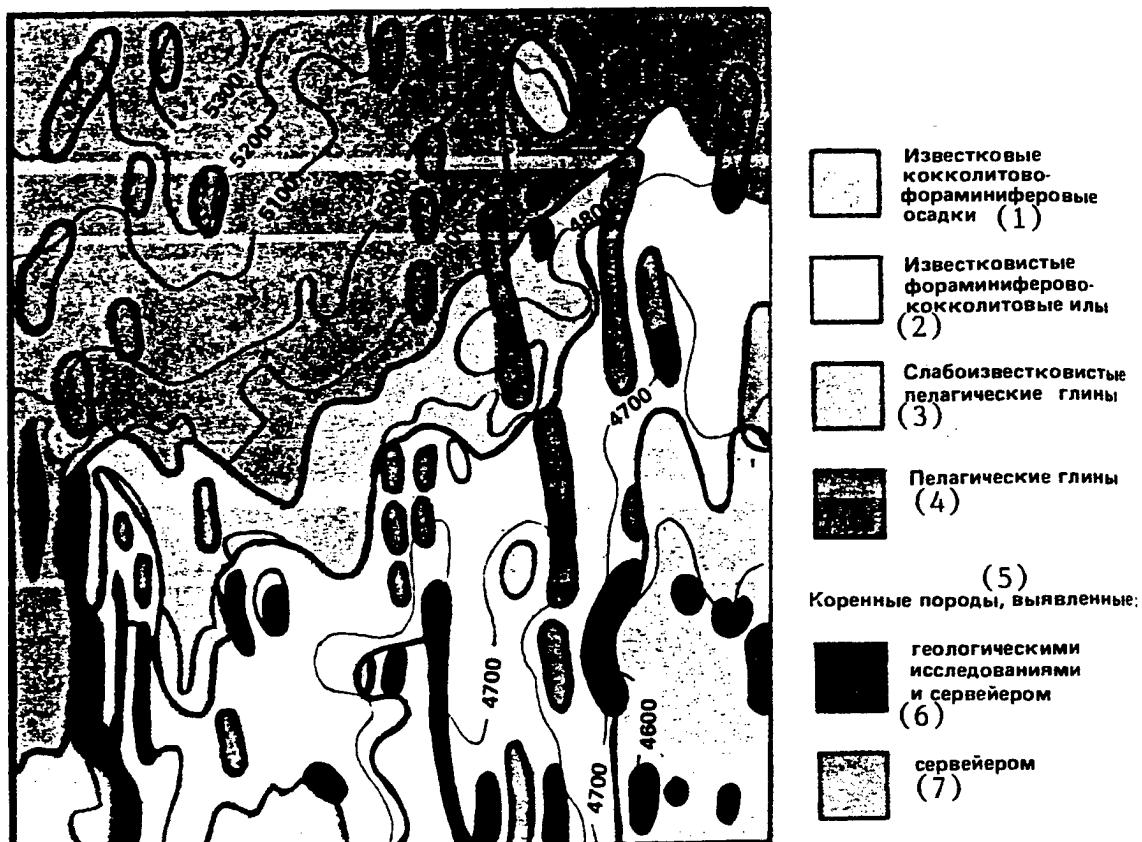
The geological work was organized at the test area with regard for the acoustic data we received. Fifty-two samples were obtained with an Okean bottom sampler, which takes samples every 1-2 nautical miles, and the self-surfacing AP-Passat bottom sampler, which raises rock every 500 m. In addition six cross sections 1-4 nautical miles long were photographed.

The test area was located in the eastern part of the Brazil Basin, adjacent to the Mid-Atlantic Ridge. In this area, ranges rising 300-500 m above the floor neighbor onto a hilly plain. The extremely rough terrain, produced by tectonic movements and volcanic activity, and rock outcroppings make the sedimentary cover diverse and irregular.

Judging from photographs of the floor and the samples, even in plain regions the soft ground often gives way to outcroppings of lava rock or large blocks, on which nodule deposits are usually found. Sediments are even more contrasting and nodules are even more irregularly distributed on the summits and slopes of seamounts.

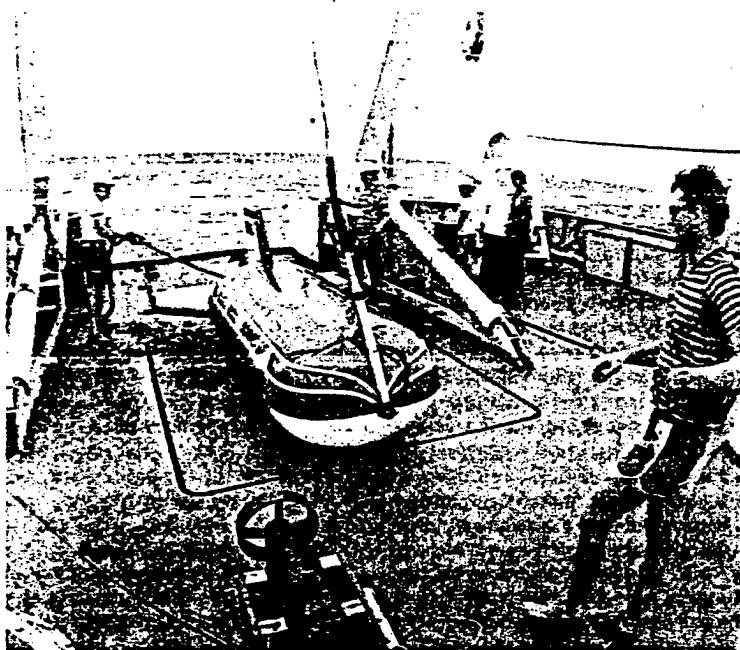
The test area was in a part of the basin where depths vary from 4,500 to 5,400 m. Biogenic deposits—carbonate and foraminifera—are encountered in shallower places, while calcareous mud and carbonate-free clay are found in deeper places.

The greatest intensity of signal scattering by the floor was detected by side-looking sonar on rises and in narrow linear zones in the plain part of the test area. It was



Distribution of Sediments and Rock Outcroppings in the Brazil Basin Test Area

Key: 1. Limestone coccolite-foraminifera deposits 2. Limestone foraminifera-coccolite mud 3. Weakly calcareous pelagic clay 4. Pelagic clay 5. Rock revealed by: 6. Geological exploration and the surveyor 7. The surveyor



Side-Looking Sonar Being Lowered Overboard

(1) Распространение конкреций:



на 30-70%  
площади дна  
(2)



на площади менее 10%  
(3)

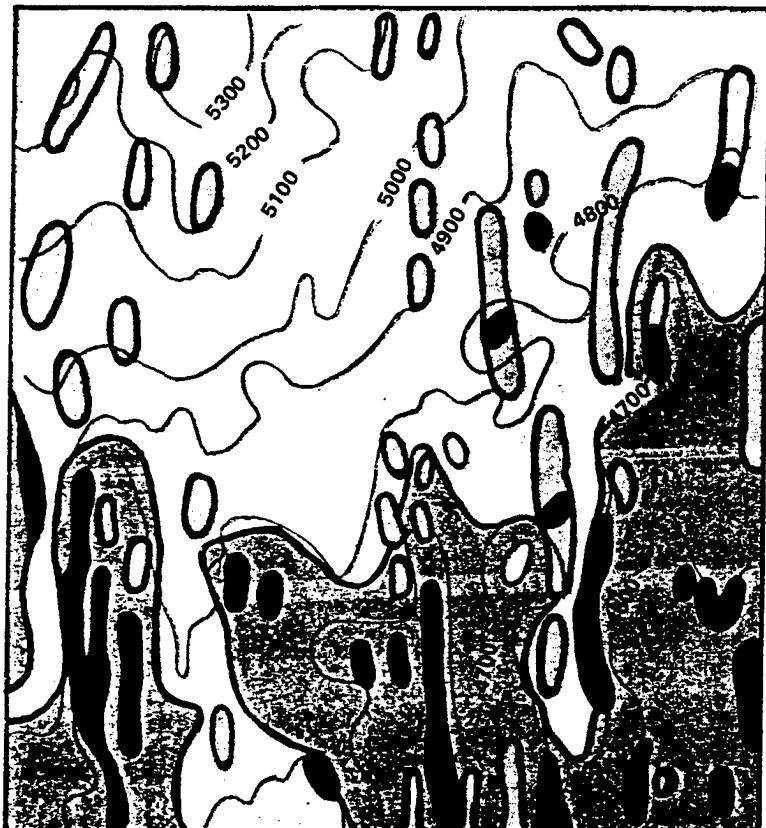
(4) Коренные породы, выявленные:



геологическими  
исследованиями  
(5)



серveyером  
(6)



Map Showing Occurrence of Nodules in the Test Area

Key: 1. Nodules occur: 2. Over 30-70 percent of the floor's area 3. Over less than 10 percent of the floor 4. Rock revealed by: 5. Geological exploration 6. The surveyor

precisely from these areas that chunks and small fragments of basalt, tuff-breccia and nodules were raised. According to photographs of the floor, rock outcroppings or compact nodule deposits corresponded to maximum scattering.

It was established by means of the samples and photographic sections that the bulk of the nodules were on the summits and on the gently sloping portions of volcanic ranges, in areas of development of carbonate deposits. Nodules covered from 30 to 70 percent of the floor area here, and usually more than 50 percent. They were replaced by pillow lava and blocks on steeper slopes. The concentration of nodules decreased dramatically (covering less than 10 percent of the area) or they were absent altogether between the ranges and on the surface of the hilly plain. However, their concentration did attain 20-50 percent in some places (usually on rock outcroppings in the plain portion of the test area). Thus disintegrated blocks surrounded by deposits containing nodules at a concentration of 10-30 percent were discovered in one of the photographic sections within the plain part of the test area. The width of the zone within which rock and nodule deposits were observed on the surface of the bottom was approximately 1 km; a soft deposit surface devoid of nodules can be seen on photographs for a distance of 0.5-1 miles to both sides of this zone.

Acoustic exploration of iron-manganese nodules began not that long ago. For the moment, work of this sort is focused primarily on checking the consistency of acoustic and geological data. In our cruise it was found to be 75-80 percent, which is explained first of all by the "spottiness" of the occurrence of ore, typical of the contrasting bottom topography of the test area in this part of the North Atlantic, and secondly by the absence of resources by which to get a fix on the bottom samplers, which often floated 200-300 m away from sampling points. In some regions of the Pacific Ocean the acoustic data was almost fully consistent with geological data.

About a month went into work in the Brazil Basin during the first cruise of the "Akademik Ioffe." Interesting and lengthy research was also conducted on the sound-scattering layers in the water column, currents, and icebergs, but that's another subject.

#### Footnote

1. Dmitriyevskiy, N. I. and Terskiy, N. Yu., "The Multibeam Echo Sounder," *PRIRODA*, No 5, 1989, pp 61-63.

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#### The Black Sea: Catastrophes Imagined and Real

917N0107B Moscow *PRIRODA* in Russian No 1, Jan 91 pp 69-74

[Article by T. A. Ayzatulin and D. Ya. Fashchuk]

[Text] Tamerlan Afiyatovich Ayzatulin is a senior scientific associate of the All-Union Institute of Scientific and Technical Information of the State Committee for Science

and Technology and the USSR Academy of Sciences. He is studying the problems of ecological chemistry and mathematical modeling of the transformation of matter in the aqueous environment. He has participated in many marine expeditions.

Dmitriy Yakovlevich Fashchuk is a candidate of geographic sciences and the leading scientific associate of the Azov-Black Sea Scientific Research Institute of Marine Fisheries and Oceanography of the USSR Ministry of Fish Industry. His scientific interests are associated with physical oceanology.

In recent years Soviet and American specialists independently detected a tendency in the Black Sea for the mean level of water containing hydrogen sulfide to rise, and an abnormally high level of such water (up to 50 meters deep) in certain areas of the water basin.<sup>1</sup> Soon after this, word surfaced of a classified report to the administrative chief of the Black Sea Fleet concerning the Crimean earthquake of 1927. It made references to "pillars of fire" and "flashes of white fire" up to 500 m high and 1.5-2 km wide on the sea near Sevastopol and Yevpatoriya.

The reaction to these events was astounding: "What would happen if, God forbid, another earthquake occurred by the shores of the Black Sea? More fires at sea? Or just one flash, one grandiose torch? Hydrogen sulfide is combustible and poisonous...and hundreds of thousands of tons of sulfuric acid would fill the sky..." (LITERATURNAYA GAZETA, No 24, 1989); "A small earthquake would be enough to cause hydrogen sulfide to reach the surface of the Black Sea and catch fire, and the seacoast will turn into a desert" (RABOCHAYA TRIBUNA, No 70, 1990); "It would be enough for a sharp decline in atmospheric pressure to coincide in time and in space with a vertical flow.... Boiling water would saturate the air with toxic fumes and inflammable gas. Where the death-dealing cloud would drift, God only knows. It might take lives along the seacoast, and in a few seconds it might transform a passenger liner into a "Flying Dutchman" (SOVERSHENNO SEKRETNO, No 5, 1989).

The list of citations could be lengthened by adding excerpts from the mass of letters written to the USSR Supreme Soviet by alarmed inhabitants of the Black Sea coast. As with most press articles, they conclude with a demand to do something right away to save the sea. "Either we will witness an unprecedented ecological catastrophe..., or the world will be provided a great example of foresight and prudent use of technological might" (LITERATURNAYA GAZETA, No 24, 1989). The authors of the newspaper publications and joint letters propose, as the "great example," implementing a project to lower the level of the hydrogen sulfide layer by pumping some of the excess hydrogen sulfide out of the depths, and in parallel with this, extracting sulfur, manganese, silver and other metals and using the hydrogen sulfide as fuel.

The proposal to use hydrogen sulfide from Black Sea water for power production was apparently suggested for the first time at the First Congress of Soviet Oceanologists in 1977 by A. S. Vasilyev, a hydrophysicist. It was discussed on several occasions in the early 1980s, but because of the unprofitability of large-scale production, it did not survive beyond popular scientific publications,<sup>2</sup> and no practical steps to implement this proposal were taken.

This 5 billion ruble project titled "Black Sea Ocean Technology," which has had a succession of several authors and developing organizations, has now been sent to the Oceanology Institute imeni P. P. Shirshov of the USSR Academy of Sciences for review. Its latest author, A. K. Ryazanov (a colleague and coworker of the former authors) proposes stopping the rise in level of water containing hydrogen sulfide by pumping 2,500 km<sup>3</sup> of water yearly from a depth of 1,200 m by pipes with a diameter of 3 m. This would be equivalent to 12 years of discharge by the Danube. Losses due to extraction of sulfur and metals from this water would be compensated by the avoidance of an "ecological catastrophe"—surfacing of the Black Sea's zone of "perpetual asphyxiation."

The city of Novorossiysk has offered land on which to develop and implement the project—doubtlessly one that is more grandiose than the plan, recently rejected after so much difficulty, to divert the water of northern rivers to the south (it proposed removing only around 6 km<sup>3</sup> of water from the northern rivers), for which reason the project has come to be called the "Novorossiysk Panama" among chemists.

There can be no doubt as to the seriousness of the intentions to save the sea after the following statement by the leader of our country from the podium of the international Global Forum for the Protection of the Environment and Development for Survival: "The upper boundary of the hydrogen sulfide layer in the Black Sea rose in recent decades from a depth of 200 m to 75 m from the surface. A little more, and it will cross over the Bosphorus threshold into the Marmara, Aegean and Mediterranean seas" (PRAVDA, 20 January 1990).

We attempted to analyze the credibility of the apocalyptic predictions, given what we know today about the nature of the Black Sea and the properties of hydrogen sulfide, and with regard for the accomplishments of mathematical modeling.

Black Sea seismicity is confined to the periphery of the Black Sea depression, while its central deep-water region is characterized by low seismicity.<sup>3</sup> In contrast to other coastal regions of the Black Sea, the Crimea is characterized by narrowly confined seismicity, the zone of which is situated along the steep continental slope as a continuous belt from Sevastopol to Feodosiya, with maximum activity at Yalta. In the last 100 years or so, around 100 5-8 point earthquakes were recorded in the Crimea, and just in 1927-1930 a burst of seismic activity was observed, accompanied by a 9-point earthquake that exceeded the famous Tashkent earthquake (1966) by a hundred times.

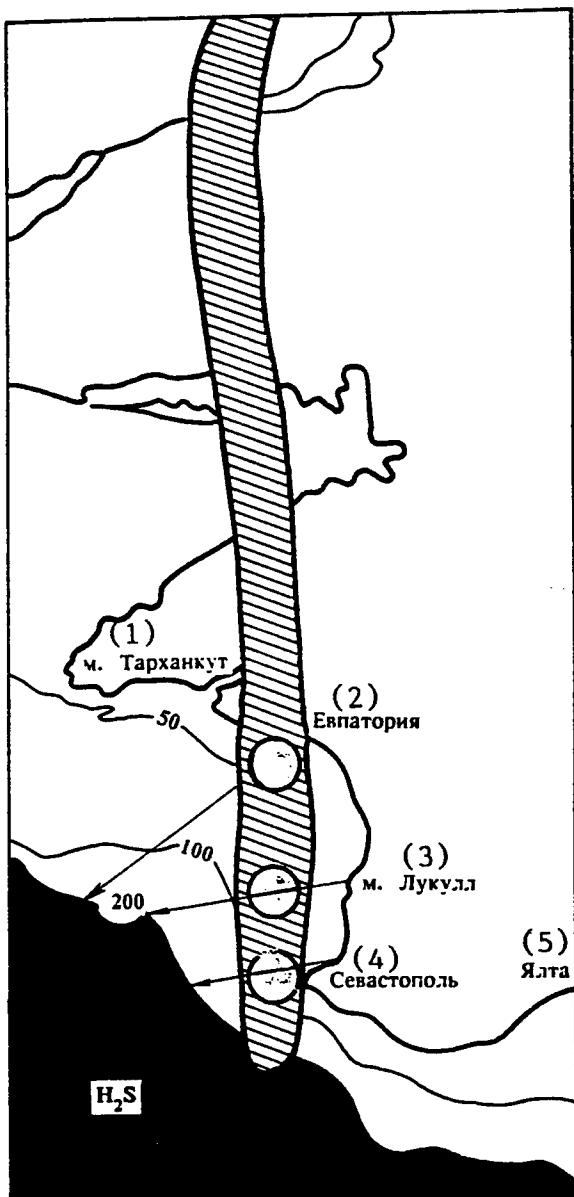
As a result of tectonic movements on 11 November 1927, the block of the Earth's crust beneath the sea, 100 km from the southern Crimean shore, dropped, while the continental block rose. The effect of this natural disaster was closely confined, and it did not spread to the main part of the sea basin occupied by the hydrogen sulfide zone. At the earthquake's epicenter, which was 25 km from Yalta, the Earth's crust beneath the portion of the sea occupied by water containing hydrogen sulfide dropped, which in no way could have caused surfacing of this water.

According to observations, during the Crimean earthquake fire flashes were noted at sea at night in a direction from Yevpatoriya, Sevastopol and Cape Lukull west (on a bearing of 255-260°). Plotting this information on the map, it is not difficult to see that the "sea burned" above water not exceeding 100 m in depth—in places where hydrogen sulfide had never occurred in the bottom water layer. The closest the boundary of the hydrogen sulfide zone (the 150-200 m isobath) comes to Sevastopol at this bearing is 60-100 km, while it is more than 200 km from Yevpatoriya, which precludes the possibility of seeing fire even at night.

The cause of the "sea fires" becomes understandable after analyzing the geological structure of the northwestern shelf of the Black Sea—a typical gas-bearing region of the World Ocean. It is crossed in the meridional direction by four major faults that separate the basic structural elements of the Black Sea region. Drilling rigs are currently extracting natural gas on the water basin within the zones of these faults. In spring 1989 an expedition of the Institute of Biology of Southern Seas of the Ukrainian SSR Academy of Sciences led by G. G. Polikarpov discovered emergences of natural gas "torches" on the sea-bed (at depths from 62 to 400 m) with a cross section from 50-70 to 200-300 m, and in one case "on a fault up to 2 miles long" (SLAVA SEVASTOPOLYA, No 139, 1989). The "sea fires" were observed on water above the Krivoy Rog-Yevpatoriya fault. Gas is not being extracted from there now, but activation of its sources by an earthquake, going as far as surfacing of "torches" and their ignition, is fully realistic.

The maximum concentration of hydrogen sulfide in Black Sea water is 13 mg/liter, which is 1,000 times less than what is necessary for 100 percent saturation and its surfacing in the form of a gas. The conditions for an explosion or for ignition of such a solution are difficult to create even in the laboratory (explosive concentrations for hydrogen sulfide in air are 4.5-45 percent, and the ignition point is 250°C). Moreover people have been utilizing open sources of hydrogen sulfide water with concentrations exceeding that in Black Sea water by hundreds of times since ancient times, and never has an explosion been noted at any of them, including for example the famous one at Matsesta. Encounters with hydrogen sulfide jets have been described in mines: They have been accompanied by poisoning of people and by change of the color of open lantern flames to green, but in distinction from methane, they were not accompanied by explosions.

Lethal concentrations of hydrogen sulfide in air are 670-900 mg/m<sup>3</sup>, the central nervous system is damaged at 270 mg/m<sup>3</sup>, and intoxication occurs at 70 mg/m<sup>3</sup>. In the real conditions of the Black Sea, given hypothetical



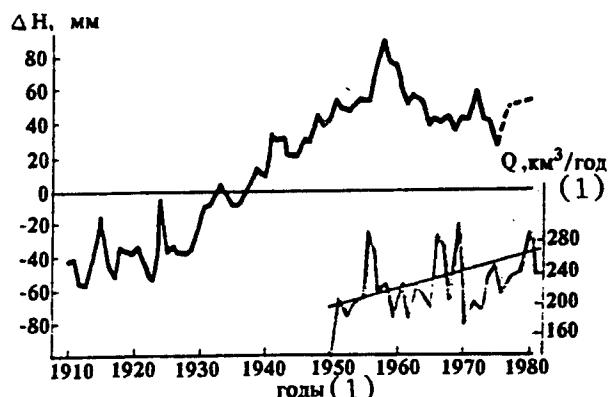
Confinement of "Sea Fires" of the Period of the Crimean Earthquake to the Krivoy Rog-Yevpatoriya Fault Zone (Shaded) Extending Near the Eastern Crimea, and Their "Remoteness" From the Hydrogen Sulfide Zone, Colored Solid Black.

Key: 1. Cape Tarkhankut. 2. Yevpatoriya. 3. Cape Lukull. 4. Sevastopol. 5. Yalta

instantaneous surfacing of abyssal waters, it would be hard to achieve even the maximum tolerable olfactory concentration in air above the sea—2 mg/m<sup>3</sup>. Meaning that we need not fear "Flying Dutchmen," and hydrogen sulfide would pose no danger to the coastal population even under the most fantastic circumstances. But what

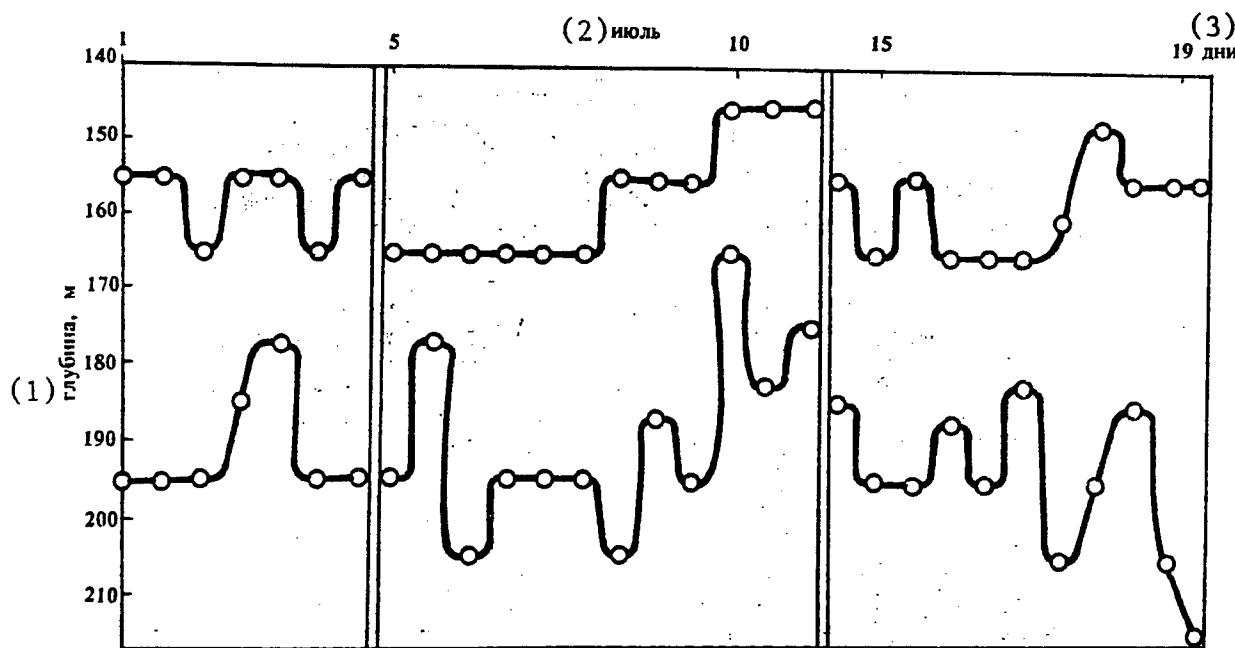
about the inhabitants of the sea, are they in danger? Such a prognosis is possible if we consider the causes determining the dynamics of the boundary of the anaerobic zone.

One of the causes might have been anthropogenic irretrievable water consumption. In the Dead Sea, for example, it attained 80 percent of the discharge of the Jordan River, and led to an increase in the salinity of the surface layer, its equalization with abyssal salinity, intensive mixing, and surfacing of water containing hydrogen sulfide. However, in the last 30 years in which rising of the boundary of the anaerobic zone of the Black Sea has been observed, the Danube's discharge (averaging 200 of the 346 km<sup>3</sup> of river water entering the sea annually) did not decrease: It grew.<sup>4</sup> In the meantime the discharge of the Dniepr remained practically constant (at 45 km<sup>3</sup>) because although water levels were higher during this period, water was also being diverted for irrigation. Thus the total river discharge into the Black Sea is increasing. In recent years, fresh water diverted for the needs of the national economy (15-20 percent of total annual discharge) has been more than compensated by nature owing to a process of increasing humidity, while the salinity of the surface layer is manifesting a decreasing trend. Consequently the anthropogenic factor is not having any fundamental influence on the hydrological structure of the open part of the Black Sea, as had occurred in the Dead Sea, and it is not a cause of the rise in the boundary of the anaerobic zone. At the same time the additional inflow of fresh water led to an increase in the difference between the densities of the surface and abyssal layers of the Black Sea. Model calculations carried out by the Sevastopol Department of the State Oceanographic Institute showed that this could reduce the depth to which oxygen-enriched water penetrates during winter convecting mixing, and that consequently it can cause the hydrogen sulfide zone to rise. Researchers from the Marine Hydrophysical Institute of the UkrSSR Academy of Sciences feel that long-period



Change in Level of the World Ocean (H, mm) and the Danube's Discharge (Q, km<sup>3</sup>/year)

Key: 1. Year



Change in Position of the Upper Boundary of the Hydrogen Sulfide Zone (the Layer of Coexistence of Hydrogen Sulfide and Oxygen) in the Vicinity of Yalta Under the Influence of Synoptic Processes

Key: 1. Depth. 2. July. 3. Days

changes in the level of the Black Sea, synchronous with fluctuations of the level of the World Ocean, which is presently rising by an average of 1.4-1.5 mm per year,<sup>5</sup> may be another factor disturbing the stability of the position of the anaerobic zone's boundary. Changes in the intensity and nature of atmospheric circulation above the sea, which in turn determine the intensity of ascending movements in the water basin, may also lead to a similar effect.

Correlation analysis of a series of average depths of the anaerobic zone's boundary in summer,  $H_s$  (m), changes in the level of the World Ocean  $\Delta H$  (mm), and changes in atmospheric (average annual  $P_{ave}$  and average May  $P_M$ ) pressure (GPa) in Yalta reveals statistically significant correlation between them:

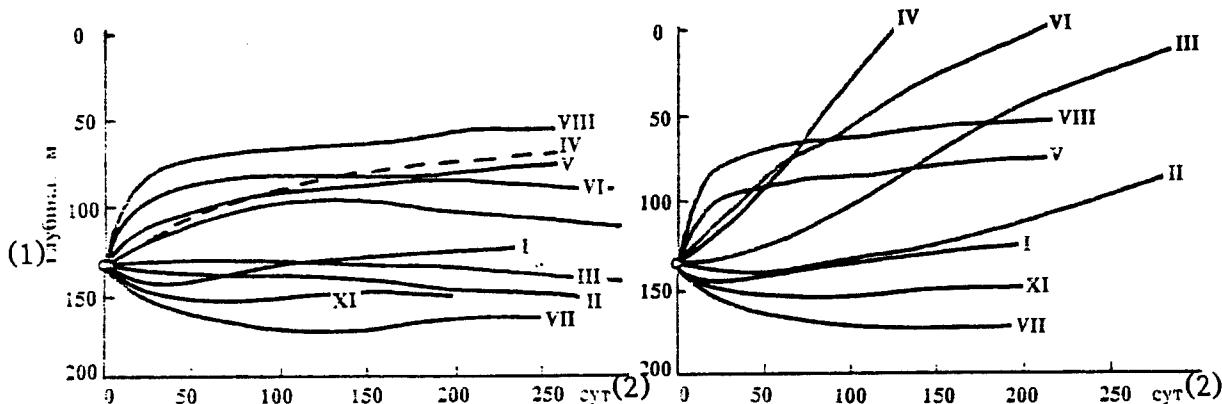
$$\begin{aligned} H_s &= 0.37\Delta H + 121.4; \\ H_s &= 5.87P_{ave} - 5,770; \\ H_s &= 2.91P_M - 2,790. \end{aligned}$$

A prediction would properly be made on the basis of these equations only under the conditions under which they were obtained, since changing environmental factors introduce their own dependencies into them. Nonetheless, simple calculations show that surfacing of hydrogen sulfide would require the level of the Black Sea to rise 330 mm, or the average May pressure in Yalta to decrease to 958.7 GPa. The former may occur (given the present rate at which it is rising) after 220 years, while the latter would be unrealistic (the lowest average May pressure in Yalta during the time of the observations was 1,002.8 GPa). Moreover all of the natural mechanisms

listed above are cyclic, such that the established tendency for the boundary of the anaerobic zone in the Black Sea to rise—apparently a product of their combined positive action—cannot be linearly extrapolated into the future. Thus there are grounds for suggesting that there is no danger to the population of the Black and even the Marmara, Aegean and Mediterranean seas from an “ecological catastrophe” resulting from long-period climatic changes.

Despite the optimistic estimates presented here, the abnormally high position of the anaerobic zone's boundary is patently clear today. It has become susceptible to the dynamic action of mesoscale eddies in the open part of the sea, and to tidal circulation in coastal regions. Can these natural mechanisms cause water containing hydrogen sulfide to surface in certain places, with woeful consequences to the inhabitants of the sea, for example during the spawning period?

In the region that is dynamically the most active—by the southern shore of the Crimea—the boundary of the anaerobic zone reacts to an increase in wind speed (a change in atmospheric pressure) after 12 hours, and this reaction lasts two days.<sup>6</sup> Its depth here in the summer period can be calculated using the formula:  $H_s = -583 + 0.73P_{at}$ , where  $P_{at}$  is the pressure reading in Yalta, offset by two days. Its surfacing would require a pressure of not more than 800 GPa. But even in group six tropical cyclones (ones of the highest power), a pressure less than 883 GPa has never been recorded.<sup>7</sup> Thus the reality of local “catastrophes” in the coastal part of the sea in response to synoptic processes is also found to be highly doubtful.



**Results of Model Calculations of the Position of the Upper Boundary of the Hydrogen Sulfide Zone in Relation to the Actual Magnitude of the Hydrogen Sulfide Source (left) and This Magnitude Increased by a Factor of 1,000 (right): Its surfacing occurs only in the case of a sea of uniform density (curves III, IV, VI) and a thousand-fold increase in magnitude.**

Key: 1. Depth 2. Days

Finally, there is one other possible mechanism responsible for the rise in the boundary of the anaerobic zone in the Black Sea—change in the output capacity of hydrogen sulfide sources as a result of anthropogenic eutrophication of the sea (an increase in the quantity of organic matter entering it). This was one of the processes determining development of hydrogen sulfide zones in shallow regions of the northwestern shelf in summer. Quantitative assessments of its contribution to the intensity of hydrogen sulfide production in the deep part of the sea were not available until recently. We programmed different variants of the hydrological structure of the sea (the distribution of vertical exchange conditions going as far as complete equalization of the density with respect to depth) in 11 computer simulation experiments<sup>8</sup> and combined them with four scenarios for sources of hydrogen sulfide with different output capacities (which varied by one to three orders of magnitude). We found that the position of the anaerobic zone's boundary is determined by the position of the layer in which the intensity of vertical exchange is minimal, and that it depends weakly on changes in the flow of hydrogen sulfide. When we used a real value for this output, one corresponding to current quantitative estimates of it, even in a sea of uniform density the boundary of the anaerobic zone not only fails to surface but even drops due to improvement of aeration of abyssal layers. Hundredfold enlargement of the output capacity of the hydrogen sulfide source raises the boundary 40 m, but even in this case it does not surface. Only thousandfold enlargement of this source can lead to such a result in a sea of uniform density. But when the water remains stratified, an “ecological catastrophe” is impossible even under these fantastic conditions.

It is astounding how quickly and easily projects to pump out the sea’s “surplus”—an extremely serious operation carried out on the body of nature—come into being. In

this case no one is interested in the “health of the patient,” which we can find out about from any oceanographic institute of the Academy of Sciences, from the Hydrometeorological Service or from the Ministry of Fish Industry. Instead, serious information is substituted by myths. In our opinion this substitution is evidence of a real social catastrophe! Unrestrained technological development of civilization, occurring on the backdrop of hypertrophic development of technocratic knowledge side by side with dystrophy of the natural sciences, has exposed us, within the life span of a single generation, to the danger of the environment’s degradation. In the more than half-century campaign to conquer nature, we know of no single victory over it that did not subsequently transform into a misfortune for the “conqueror,” and probably for his offspring as well. On the other hand our sense of oneness with nature, our desire and ability to think about the future, and the elementary instinct of self-preservation have atrophied.

Luckily the fast movement forward of the project “to save the Black Sea,” which began in 1984, has now been halted. Judging from the newspapers, its authors are now asking not for R5 billion, but only R250,000-300,000, to solve the “fundamental technological problems,” with a guaranteed economic impact of R89.9 million (SLAVA SEVASTOPOLYA, No 63, 1990). But no less was also guaranteed by the cascade of Dniepr reservoirs, by diversion of waters from Central Asian rivers, by the Danube-Dniepr canal, by water management measures on the Volga and Kuban, and by “development” of Lake Baikal. What all of this ends with, we are fabulously aware today.

Today, we can list not less than a dozen decisions and decrees of soviet and party organs at both the union and republic levels having to do with the ecology and environmental protection of the Black Sea basin. They all contain the terms "reinforce," "unite," "concentrate," and so on. The phrases "comprehensiveness of research," "a systems approach" and "ecological monitoring" are invariably present in the State Science and Technology Committee projects "Black Sea" and "Seas of the USSR," as well as in the project "Programs of Biospheric and Ecological Research of the USSR Academy of Sciences to the Year 2015" and in the comprehensive specific-purpose program of the USSR Ministry of Fish Industry "South." Nonetheless, as we can see, the problems are still around! Meaning that the solutions are not to be found in directives and programs.

Absence of culture in this century of scientific and technical revolution has led to a situation where the commandment "do no harm" has been replaced in the activity of the sorry bureaucrat by the thoughtless motto "win some, lose some," which masks his real position: "It won't matter to me after I'm gone." The sad results of such a substitution have fully validated the prophecy that "the road to damnation"—ecological in particular—is littered with good intentions. Our hope is that the changes that have begun in the country will permit us to avoid this end, and that they will spare us in the future of a real catastrophe, one which is presently threatening not only the Black Sea but also all of nature, and consequently both ourselves and our children!

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#### Maximal Wind Waves in White Sea

917N0114C Moscow *METEOROLOGIYA I GIDROLOGIYA* in Russian No 1, Jan 91 (manuscript received 8 Feb 90) pp 86-91

[Article by V. B. Korobov, Northern Territorial Administration for Hydrometeorology]

UDC 551.466.31(268.46)

[Abstract] In contrast to numerical simulation of extreme wave spectra carried out for the Gulf of Alaska by F. Augustine, et al., a new approach is proposed for simulation of such extremal synoptic situations. The approach is based on an analysis of multiyear statistical data on storm winds and the synoptic situations causing them. The work involved simulation of an extremal storm in the form of a series of successive synoptic charts plotted at intervals of not more than three hours. The White Sea was selected as the object of study due to the availability of a multiyear archives of synoptic charts and a dense network of shore and island hydrometeorological stations. Simulation of extremal storms yielded the maximal parameters of wind waves at two points in internal regions of the White Sea. A study was made to determine how they are related to existing concepts on maximal waves in the White Sea obtained within the framework of traditional methods by means of extrapolation of regime functions. This made it possible to evaluate the probability of appearance of extremal storms. Two storms were simulated on the basis of statistical data on wind speed and the trajectories of movement of cyclones during an approximately 50-year period. The proposed algorithm for simulating storms can be used for a conservative (upward) estimate of maximal wave parameters in a 50-year period. Figures 3; references 15: 13 Russian, 2 Western.

#### Fine Vertical Structure of Temperature in Subarctic Front Zone (Mega-Test Range)

917N0103A Moscow *DOKLADY AKADEMII NAUK SSSR* in Russian Vol 316 No 2, Jan 91 pp 468- 474

[Article by V. V. Navrotskiy, A. M. Levenko and Ye. P. Pavlova, Pacific Ocean Oceanological Institute, Far Eastern Department, USSR Academy of Sciences, Vladivostok]

UDC 551.465

[Abstract] The fine vertical structure of the temperature field in the upper 500-m layer in the northwestern Pacific Ocean caused by large-scale structures such as fronts and eddies is analyzed. The observations were

made during the period 14-30 June 1987 on the Akademik Aleksandr Nesmyanov research ship using an "Istok" probe with measurements at an interval of about 1.5 m in depth. The stations were occupied along eight meridional runs from 150 to 157°E each degree in longitude and 15' in latitude from 38 to 42°30'N. A figure shows the temperature distribution at the 100-m horizon and the structure of this zone (position of various fronts and eddies). The pertinent phenomena are examined in detail for the case of run 5 and all possible interactions are considered. Two probable mechanisms of the formation of the observed layers with sharply different vertical temperature gradients are examined: horizontal intrusions and internal gravity waves. The intrusions which naturally arise in zones with great slopes of isopycnic surfaces are usually accompanied by secondary stratification with very sharp gradients caused by the diffusion of heat and salt. Operation of this mechanism could neither be confirmed nor refuted. The governing factor, however, is more likely internal waves. The observed great complexity of fine structure clearly indicates a need for more detailed analysis of the relationship between fine structure and large-scale hydrophysical structures. Figures 4; references: 3 Russian.

#### **Spatial-Temporal Scales of Synoptic Inhomogeneities in Ocean Surface Temperature Field in Gulf Stream Region**

917N0068A Moscow OKEANOLOGIYA in Russian  
Vol 30 No 6, Nov-Dec 90 pp 885-890

[Article by S. K. Gulev and I. M. Yashayayev, State Oceanographic Institute, Moscow]

UDC 551.465.62

[Abstract] In an earlier article (S. K. Gulev, et al., OKEANOLOGIYA, Vol 28, No 5, pp 721-727, 1988) correlation-spectral analysis was used in obtaining estimates of the spatial scales of ocean surface temperature (OST) in the Gulf Stream-North Atlantic region. Proceeding on the basis of this earlier work, a spatial-temporal analysis of ocean surface temperatures was made over a long period which revealed some important features of OST variability in this region. The analysis was made using charts for the period October 1982-February 1984 and for 1986 transmitted by the Halifax Radiometeorological Center. A special approach was used in examining synoptic temperature variability in coordinates referenced to the undisturbed position of the Gulf Stream and North Atlantic Current. This research indicated the effectiveness of use of regular data on ocean surface temperature in analyzing complex dynamic processes associated with instability and meandering in western boundary currents. This made it possible to detect a spatial-temporal cyclicity in temperature variability and to evaluate the characteristics of wave disturbances propagating along the Gulf Stream jet in northeasterly and southwesterly directions. Figures 3; references 24: 10 Russian, 14 Western.

#### **Variability of Characteristics of Subsurface Salinity Maximum During Passage of Tropical Cyclones**

917N0068B Moscow OKEANOLOGIYA in Russian  
Vol 30 No 6, Nov-Dec 90 pp 891-896

[Article by A. S. Sergiyenko and V. A. Sosnin, Pacific Ocean Oceanological Institute, Far Eastern Department, USSR Academy of Sciences, Vladivostok]

UDC 551.512.2:551.465

[Abstract] An attempt is made to examine the influence of a tropical cyclone on the salinity field, especially the subsurface salinity maximum and the variability of its characteristics. The analysis was made for a region in the northwestern part of the Pacific Ocean bounded by the coordinates 15-30°N and 10-140°E. The hydrological survey data were collected in the summer of 1980. The characteristics of tropical cyclones were determined from facsimile surface pressure charts. The repeated hydrological surveys for this region made it possible to obtain data on the background distribution of oceanological characteristics and also on their variability caused by the passage of tropical cyclones. An analysis of in situ data indicated a correlation between the subsurface salinity maximum and processes of interaction between the ocean and the atmosphere. This is manifested most clearly during the passage of a tropical cyclone due to a sharp intensification of interaction processes under stormy conditions. In the nature of changes in the subsurface salinity maximum it is possible to trace a dependence on the characteristics of tropical cyclones: intensity of tropical cyclone, rate of movement and radius and velocity of maximal wind. Figures 3; references: 8 Russian.

#### **Current Velocity in Near-Bottom Layer in Region of Development of Ferromanganese Nodules in Pacific Ocean (Clarion-Clipperton Province)**

917N0068C Moscow OKEANOLOGIYA in Russian  
Vol 30 No 6, Nov-Dec 90 pp 897-905

[Article by T. A. Demidova, Ye. A. Kontar and A. M. Belyayev, Oceanology Institute imeni P. P. Shirshov, USSR Academy of Sciences, Moscow]

UDC 551.465.53

[Abstract] The results of processing and analysis of experimental data from observations of the velocities of near-bottom currents in the northeastern part of the tropical zone of the Pacific Ocean are presented. The measurements were made on the 41st cruise of the Dmitriy Mendeleev research ship in the spring of 1988. The observation horizon was 6 m from the ocean bottom and the observation duration was 36 days. A spectral analysis of time series was made and their filtering was carried out. A complex structure of variability of velocities in the near-bottom layer was detected with respect

to both amplitude and direction. A correlation was found between the direction of the near-bottom currents and bottom relief. The periodic intensification and weakening of current velocities are favorable for maintaining the dynamic process of precipitation of the particles which are transported and the entrainment of the finest material into the transport. The collected information is important for constructing models of structure of the near-bottom boundary layer when studying the genesis and conditions for the deposition of ferromanganese nodules. Figures 5; references 19: 7 Russian, 12 Western.

### Topographic Rossby Waves Over Random Bottom Relief

917N0068D Moscow OKEANOLOGIYA in Russian Vol 30 No 6, Nov-Dec 90 (manuscript received 3 Jan 90) pp 906-915

[Article by D. Sengupta, L. I. Piterbarg and G. M. Reznik, Oceanology Institute imeni P. P. Shirshov, USSR Academy of Sciences, Moscow]

UDC 551.496.4

[Abstract] A study was made of a Rossby wave over random rough bottom relief. In contrast to almost periodic topography, such relief is incapable of sustaining the propagation of low-frequency large-scale topographic oscillations. Rossby waves over a random bottom were investigated using the localization phenomenon for waves in random media discovered by P. W. Anderson (PHYS. REV., Vol 109, No 6, pp 1492-1503, 1958). Section 2 describes the important aspects of this phenomenon. The same approach has been used in studying surface waves (P. Devillard, et al.) and topographic Rossby waves (S. A. Molchanov, et al.). However, the analytical results obtained earlier are applicable only to a narrow range of variability of the principal determining parameters of the problem: frequencies and wavelengths and relief characteristics. The proposed statistical simulation method makes it possible to investigate a considerably broader range of the enumerated parameters. Section 2 gives a concise summary of the principal facts from localization theory. Section 3 describes the considered model, including the parametrizations of bottom relief used, and outlines a method for computing the localization length. Section 4 discusses the results of numerical experiments. Further research possibilities along these lines are suggested. Figures 8; references 24: 13 Russian, 11 Western.

### Influence of Shear Currents on Kinematic Characteristics of Internal Waves

917N0068E Moscow OKEANOLOGIYA in Russian Vol 30 No 6, Nov-Dec 90 pp 932-935

[Article by K. D. Sabinin and T. M. Uspenskaya, Acoustics Institute imeni N. N. Andreyev, Moscow]

UDC 551.466

[Abstract] The results of computations of the dispersion characteristics of internal waves on the basis of a solution of the Taylor-Goldstein equation and space-time spectral analysis were compared. In the example of an analysis of the space-time spectra of internal waves obtained as a result of processing of in situ measurements in tropical regions of the Indian and Atlantic Oceans it is shown that allowance for the current profile makes it possible to achieve a considerable improvement in consistency between the computed dispersion characteristics of internal waves and the results of spectral processing. The presence of a strong current in the upper layer of the ocean should result in a considerable anisotropy of the surface manifestation of internal waves and the conditions for such manifestation may vary with an inertial period. The conclusion is drawn on the basis of computations for model profiles of density and current velocity that drift currents and inertial oscillations in the upper layer of the ocean may exert a considerable influence on the intensity of manifestation of internal waves on the ocean surface and accordingly, on the conditions for their observation, which is important for solving problems in remote monitoring of geophysical fields. Figures 4; references 4: 3 Russian, 1 Western.

### Semiempirical Method for Quantitative Determination of Impurities in Sea Water by Fluorimetric Lidars

917N0068F Moscow OKEANOLOGIYA in Russian Vol 30 No 6, Nov-Dec 90 pp 1027-1030

[Article by E. I. Krasovskiy, V. I. Repin, V. M. Sidorenko and Ye. V. Baulin, State Optical Institute imeni S. I. Vavilov, Leningrad]

UDC 551.464.6/7

[Abstract] A method is proposed for improved determination of the fluorescence parameter  $\Phi_0$ , used as a quantitative characteristic of fluorescent admixtures, differing considerably from the traditional empirical method widely used in the diagnosis of phytoplankton, dissolved organic matter and petroleum products with calibration against the Raman scattering of water. In particular, use is made of the parameter  $\Phi_0^A$ , differing from the parameter  $\Phi_0$  by a constant factor equal to the ratio of the form factors of the bands. The difficulties in determining the pertinent terms of the expression for this parameter, which reduce efficiency and accuracy of the method, are discussed. In overcoming these problems use is made of the results of intensity measurements at the maxima of the fluorescence and Raman signal bands from experimentally registered spectrograms. Procedures are outlined which make it possible to determine other terms which have caused difficulties in previously employed processing methods. The described method

makes it possible to simplify the normalization procedure and avoid measurements in the wing of the fluorescence band of sea water in remote measurements. Figure 1; references 10: 8 Russian, 2 Western.

### Influence of Earth's Rotation on Internal Waves Behind Moving Pressure Region

917N0105A Kiev MORSKOY GIDROFIZICHESKIY ZHURNAL in Russian No 6, Nov-Dec 90 pp 3-10

[Article by S. F. Dotsenko, Marine Hydrophysics Institute, Ukrainian Academy of Sciences, Sevastopol]

UDC 551.466.81

[Abstract] The plane problem of generation of waves by a moving atmospheric pressure anomaly is analyzed. The research was carried out in a general linear formulation taking into account the Earth's rotation and on the assumption of a continuous density stratification. Quantitative estimates of the amplitudes of internal waves were obtained for an ocean with an isolated density jump. Earlier research along these lines made no allowance for the Earth's rotation, was based on the assumption that density stratification is uniform or was based on the quasistatics approximation. The new research reveals that the Earth's rotation exerts an influence on the process of generation of waves by moving atmospheric anomalies. Rotation plays a fundamental role in the formation of wave fields if the characteristic horizontal scale of the external disturbance or the rate of movement of an atmospheric disturbance are quite great. Rotation effects are manifested under conditions of wave wake generation and in the modal composition of the wave field, kinematic and dynamic characteristics of nonattenuating waves. The Earth's rotation thus leads to a transformation of the very process of development of wave movement. Figures 3; references 12: 10 Russian, 2 Western.

### Vertical Transfer Phenomenon in Black Sea

917N0105B Kiev MORSKOY GIDROFIZICHESKIY ZHURNAL in Russian No 6, Nov-Dec 90 pp 34-41

[Article by S. G. Boguslavskiy and I. K. Ivashchenko, Marine Hydrophysics Institute, Ukrainian Academy of Sciences]

UDC 551.465.45(262.5)

[Abstract] Information is generalized on the intensity of the vertical transport phenomenon in the entire depths of the Black Sea. The emphasis is on usefulness of the vertical exchange coefficient  $K_z$ , which takes turbulent and advective transport processes into account. The climatic T, S characteristic curves, flows of heat and salt and rate of transformation of lower Bosphorus waters were used in determining the  $K_z$  values for the entire sea:

in the wave mixing, active and cold intermediate layers, in the halocline, in deep and near-bottom waters (the situation in each of these layers is discussed in detail). The annual  $K_z$  values are described for the active layer of the sea and an increase in this coefficient with transition from the centers of cyclonic circulations to their peripheries is noted. A series of tables and graphs also provides a detailed picture of these distributions. The vertical distribution of  $K_z$  characterizes the total transport of substance at different sea depths and can be widely used in hydrophysical and hydrochemical computations. Figures 3: references 10: 9 Russian, 1 Western.

### Vertical Hydroacoustic Structure of Central and Intermediate Waters of Tropical Atlantic

917N0105C Kiev MORSKOY GIDROFIZICHESKIY ZHURNAL in Russian No 6, Nov-Dec 90 (manuscript received 18 Oct 89) pp 48-56

[Article by N. P. Bulgakov, P. D. Lomakin, N. M. Kovaleva and V. N. Cheremin, Marine Hydrophysics Institute, Ukrainian Academy of Sciences, Sevastopol]

UDC 551.463.21

[Abstract] The speed-of-sound field was computed for the northern part of the Tropical Atlantic. The vertical hydroacoustic structure of central and intermediate waters was investigated from scientific research ships during 1986-1988. Soundings were to depths 1000-1500 m at points of a grid with an interval 40 miles in longitude and 90 miles in latitude. Observations were made at 5-m depth intervals; a total of 2,500 soundings were made. A distinguishing feature of this region is the presence of numerous local sound channels in the subsurface and intermediate water layers. The characteristics of these formations are described and the reasons for their formation are discussed. There is a correlation between the presence of the characteristic local wave guides in subsurface and intermediate structural zones and regions of interaction between the principal water masses and elements of large-scale circulation. The strongest local sound channels were discovered in the region of interaction between central water masses of southern and northern origin in the layer 200-500 m (width 20-60 m, lifetime one-two months). The northwestern part of the Tropical Atlantic is characterized by the most complex form of the  $C(z)$  profile. Over the course of a year the probability of detection of structures with five-eight local sound channels in the layer 100-800 m attains 30-40 percent. Local channels are rarely encountered in the eastern part of the equatorial anticyclonic circulation. The computed ray patterns revealed the influence of sound field inhomogeneities on the trajectory of acoustic rays. Individual local sound channels in the studied regions of the ocean are capable of concentrating a considerable part of the energy of the sources of sound oscillations situated near their axes. Figures 6; references 10: 6 Russian, 4 Western.

**Adiabatic Invariants of Large-Scale Atmospheric Processes**

917N0073A Moscow *IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ATMOSFERY I OKEANA* in Russian Vol 26 No 12, Dec 90 pp 1223-1236

[Article by M. V. Kurganskiy and M. S. Tatarskaya, Atmospheric Physics Institute, USSR Academy of Sciences]

UDC 551.513

[Abstract] The principal results applying to the fundamental concepts of vortex charge and potential vorticity, including those obtained by A. M. Obukhov, and their practical applicability in meteorology are concisely summarized. An analogy between the law of vortex charge conservation in hydrodynamics and the law of conservation of an electrical charge in electrodynamics is discussed. A form is proposed for writing the equation for the transformation of potential vorticity in isentropic coordinates. This makes it possible to formulate a constructive approach to the problem of diagnosis of large-scale fields of heat inflows, as is illustrated by the example of specific computations made using a simplified method on the basis of FGGE data. On the basis of these same data examples are given of the construction of "invariant tubes" (enclosed between surfaces of constant potential vorticity and surfaces of constant potential temperature). For the first time on the basis of the processing of observational data for the entire FGGE period computations were made of the temporal variation of the mass of the principal "invariant tube" (with potential vorticity values characteristic for cyclonic processes), which is an important climatic characteristic of the atmosphere. Figures 4; references 20: 11 Russian, 9 Western.

**Method for Determining Seasonal Thermocline Self-Similarity Parameter**

917N0092A Moscow *TRUDY VSESOYUZNOGO NAUCHNO-ISSLEDOVATELSKOGO INSTITUTA GIDROMETEOROLOGICHESKOY INFORMATSII - MIROVOGO TSENTRA DANNYKH: VOPROSY PRIKLADNOY OKEANOLOGII* in Russian No 144, 1988 pp 26-33

[Article by Yu. V. Gemish]

[Abstract] The self-similarity of the vertical temperature profile in the seasonal thermocline is an established fact. The self-similarity parameter  $\alpha$  is a convenient characteristic of the hydrological regime of waters because it characterizes the behavior of the thermocline as a whole, can replace a number of characteristics, is computed relatively simply and objectively reflects the basic behavior of hydrological processes. A study was made of the error in determining the  $\alpha$  parameter as a function of the accuracy in determining a series of other pertinent parameters at the upper and lower boundaries of the seasonal thermocline. The relative merits of use of cubic spline (CS) and piecewise linear (PL) approximations for this purpose were compared on the basis of soundings each 5 m vertically in the Guinea and Amazon test ranges. It was found that in determining  $\alpha$  the CS approximation is unquestionably advantageous for a smooth seasonal thermocline, whereas for a stratified seasonal thermocline the PL approximation is more acceptable. The procedures outlined in the article were successfully used in processing temperature profiles for the North Atlantic. Figures 4; references: 8 Russian.

### Hydrometeorological Phenomena Resulting in Natural Calamities and System for Their Prediction

917N0114A Moscow METEOROLOGIYA I  
GIDROLOGIYA in Russian No 1, Jan 91 (manuscript received 11 May 90) pp 5-15

[Article by A. A. Vasilyev, USSR Hydrometeorological Scientific Research Center]

UDC 551.515.9:551.509.32(47+57)

[Abstract] Different types of hydrometeorological phenomena observed in the territory of the USSR which inflict losses on the national economy or which cause natural calamities are discussed (a table lists the number of different dangerous phenomena observed in the USSR during 1986-1988). The process of preparation of predictions of dangerous phenomena at operational subdivisions is examined with emphasis on the tie-in to the main WMO global systems (a diagram shows the operations of the warning system of the USSR Meteorological Service). The types of existing methods for predicting hydrometeorological phenomena are classified (each of these are briefly described). The progress in improving prediction efficiency for Moscow during the period 1936 through 1989 is reviewed, as well as the prospects for increasing success in forecasting, especially in super-short-range periods. It is emphasized that even the most perfect prognostic model is useless without a correct description of the initial state of the atmosphere (objective analysis of meteorological fields on a global scale). Any improvement in hydrodynamic models must be accompanied by a corresponding improvement in observation, telecommunication and data processing systems. Figures 3.

### Multielement Image Correction System

917N0110A Tomsk OPTIKA ATMOSFERY in Russian Vol 3 No 12, Dec 90 pp 1235-1243

[Article by V. P. Lukin; Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 538.566:551.511.6

[Abstract] The first step in adaptive correction in telescopes is the use of systems for the processing (compensation) of image displacements in which special devices are usually used for measuring the center of gravity of the formed optical image. Such a procedure has already been introduced in a number of major telescopes. Since this is only the first step in attaining the desired results, the purpose of this research was to demonstrate the effectiveness of use of a segmented four-element mirror, each of whose elements registers only tilts in two perpendicular directions. The wave front detector consists of four identical devices for measuring the position of the center

of gravity of the image within the limits of each subaperture. The physical picture of what occurs in different adaptive correction stages is discussed. The limiting resolution for the proposed upgraded optical system is analyzed, revealing significant improvement. Figures 2; references 8: 6 Russian, 2 Western.

### Polynomial Expansion of Atmospheric Aberrations

917N0110B Tomsk OPTIKA ATMOSFERY in Russian Vol 3 No 12, Dec 90 (manuscript received 21 May 90) pp 1244-1248

[Article by K. V. Shishakov and V. I. Shmalgauzen, Physics Faculty, Moscow State University imeni M. V. Lomonosov]

UDC 535.416.3

[Abstract] In describing phase distortions of light fields on atmospheric paths it is customary to use their expansion into modes in a system of base functions. A number of variants for solution of this problem have been published, but all involve considerable difficulties. J. Noll (JOSA, Vol 66, No 3, pp 207-211), 1976) sought to simplify the problem by use of orthonormalized polynomials. Zernike polynomials, for example, can be used for circular apertures, but their use for receiving apertures of a different configuration is not always feasible. The problem of choice of optimal orthonormalized base functions for use during retrieval of atmospheric aberrations on the basis of measurement data is examined for such cases. It is shown that problems in optimal approximation of atmospheric aberrations and problems in wave front retrieval when using actual measurement data in essence lead to identical equations for base functions, differing only with respect to the choice of the weighting function. A system of polynomials is proposed which makes it possible to expand aberrations for receiving apertures of an annular form. It is shown that these same polynomials decrease the error in reproducing the wave front for a circular aperture, for example, by approximately 10 percent in comparison with Zernike polynomials. Figure 1; references 7: 5 Russian, 2 Western.

### Statistical Model of Signal in Synthesis of Images of Small Objects by Active Interferometry Method

917N0110C Tomsk OPTIKA ATMOSFERY in Russian Vol 3 No 12, Dec 90 pp 1249-1257

[Article by A. L. Volpov, Yu. A. Zimin and V. N. Lopatkin, Astrofizika Scientific Production Association, Moscow]

UDC 535.317

[Abstract] An analysis was made of the statistical characteristics and the elementary probability law for a signal registered when using the active interferometry method for the synthesis of images of small objects observed

through a turbulent atmosphere. Two types of signals are examined whose difference is attributable to the relation between the diameter of the radiating apertures and the correlation radius of the optical field phase distortions. The dependence of the statistical characteristics on distance between the radiating apertures and the spatial interval of its change are analyzed for both cases. It is shown that the elementary probability law for such signals conforms to a lognormal law. Its dependence on the dispersion of optical field phase distortions and the number of independent spatial and spatial-frequency regions of the registered signal was investigated. It is shown in what cases the probability density function tends to a normal law. Figures 3; references 8: 6 Russian, 2 Western.

### Compensation for Thermal Defocusing of Laser Radiation in Distant Field

917N0110D Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1258-1268

[Article by I. Yu. Polyakova and A. P. Sukhorukov, Physics Faculty, Moscow State University imeni M. V. Lomonosov]

UDC 621.378.325

[Abstract] For the time being only a small number of theoretical and experimental studies have been published on the characteristics of radiation in the distant field in the case of a nonuniform propagation path and on the behavior of a beam beyond a layer of a nonlinear medium. Accordingly, this review examines the literature on the transmission of powerful optical radiation through fixed and moving defocusing media with thermal nonlinearity. Three subjects are examined: 1) thermal defocusing, fundamental approximations and initial equations, 2) thin and distributed nonlinear lenses, 3) numerical and laboratory experiments for compensating thermal defocusing. The characteristics of radiation in the distant zone are studied in approximations both with and without allowance for aberrations. The effectiveness of compensation of nonlinear distortions by means of control of the wave front at entry into a nonlinear medium is analyzed. The results of theoretical computations are compared with known experimental data. Figures 4; references: 3 Russian.

### Experimental and Theoretical Research on Efficiency of Adaptive Focusing of Radiation in Nonlinear Medium

917N0110E Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1273-1278

[Article by F. Yu. Kanev, O. A. Mitrofanov, V. V. Popov and S. S. Chesnokov, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk; Moscow State University imeni M. V. Lomonosov]

UDC 621.373.826

[Abstract] A theoretical and experimental study was made of a "slow" adaptive system intended for compensation of stationary thermal blooming in a moving regular medium. Algorithms increasing the stability of control of the phase of a laser beam under conditions of the natural noise inevitably arising in a laboratory experiment are proposed and analyzed. The experimental and theoretical data characterizing control efficiency are compared. A diagram illustrates the proposed system for adaptive focusing of radiation. A laser beam is directed into a phase formation system consisting of two telescopes and a phase corrector (elastic mirror). After reflection from the mirror and passage through one of the telescopes the beam enters a cell filled with a fuchsin alcohol solution. Medium flow is simulated by rotation of the cell at a stipulated angular velocity. The beam image on a screen is registered by a TV camera and is sent to a computer where the main parameters of the light field are computed and signals are shaped for mirror control. A mathematical model of the adaptive array is presented. Particular attention is given to an algorithm for increasing the stability of adaptive correction with respect to noise in the optical-electronic feedback circuit. The experimental work done with this system indicates that the five-dimensional control base introduced in this study and the five-dimensional quality vector test related to it are not excessive and with compensation for wind refraction in a regular medium are close to optimal. Figures 3; references: 2 Russian.

### Phase Correction of Nonlinear Distortions of Laser Beam on Vertical Atmospheric Path

917N0110F Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 (manuscript received 30 Sep 90)  
pp 1279-1285

[Article by P. A. Konyayev, V. P. Lukin and B. V. Fortes, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 621.378.225

[Abstract] The effectiveness of phase correction during propagation of powerful radiation on a vertical atmospheric path is examined. Numerical simulation is used in a study of thermal blooming of a coherent beam. Although this research is a continuation of earlier work, a more systematic study is made of such factors as the intensity of the initial beam, the dependence of wind direction on altitude above the ground, the number of degrees of freedom of flexible and segmented mirrors and some variants of joint influence of the enumerated factors. Tabulated data indicate that a change in wind direction with altitude radically changes the relation of contributions of lower aberrations and thereby exerts a significant influence on the effectiveness of a modal mirror. With an increase in the amplitude of change in wind direction there is a decrease in the contribution of aberrations not having "circular" symmetry (that is, not

invariant to rotation of the coordinate system) and vice versa, there is an increase in the contribution of aberrations having such symmetry (defocusing and spherical aberration). The approximation of a phase screen situated in the plane of the radiating aperture introduced in this study leads to what is known to be an exaggerated correction accuracy, but this factor is decisive only in the case of a large number of mirror degrees of freedom. Figures 4; references 8: 4 Russian, 4 Western.

### Optimal Phase Correction of Focused Beams in Randomly Inhomogeneous Medium

917N0110G Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1294-1299

[Article by V. P. Lukin and M. I. Charnotskiy, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 621.375.826:535.3

[Abstract] An algorithm for choice of the optimal phase in the correction of turbulent fluctuations of a focused Gaussian beam is examined. Intensity behavior is investigated. The continuum integration method is used in the computations. It is shown that in order to optimize the mean intensity on the axis of a focused Gaussian beam it is necessary to use a phase conjugation algorithm for correction. As the correcting algorithm use was made of a spherical wave computed in the smooth perturbations method approximation. It is shown that the use of the perturbations method in solving problems related to the propagation of beams corrected by any method is more justified than for radiation with fixed characteristics because the objective of correction is compensation for perturbations introduced by the medium. The case of weak perturbations is more typical for such beams. Analysis on the basis of perturbations makes it possible to evaluate the conditions for effective use of adaptive optical systems and to determine the requirements on their characteristics. References: 10 Russian.

### Synthesis of Algorithm for Functioning of Adaptive Optical System

917N0110H Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1300-1303

[Article by S. V. Butsev]

UDC 621.396:535

[Abstract] All presently developed adaptive algorithms for sighting through a turbulent medium under a priori indeterminacy conditions for phase-conjugate adaptive optical systems have been obtained using an adaptive Bayes approach by means of solution of the maximal probability equation. However, the solution of this equation involves great mathematical difficulties, necessitating search for simpler solutions which can be represented in a form convenient for subsequent application.

Recurrent methods, making it possible to obtain solutions at a real time scale, are highly promising for this purpose. An adaptive filtering algorithm in which adaptation is accomplished directly by adjustment of the filter amplification coefficients has therefore been developed applicable to the problem of obtaining the image of a remote point object undistorted by the turbulent atmosphere. The examined phase-conjugate adaptive optical system includes a detector of wave front distortions of the Hartmann type. A block diagram of the adaptive filter is presented and discussed and the corresponding relations are derived. The conditions under which the proposed approach will be valid are analyzed. Figure 1; references: 5 Russian.

### Model of Slit Beam in Research on Adaptive Correction of Thermal Blooming of Laser Radiation on Extended Inhomogeneous Atmospheric Paths

917N0110I Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1304-1306

[Article by V. L. Dmitriev, V. B. Kasperskiy, V. P. Lukin and V. V. Sychev, Astrofizika Scientific Production Association, Moscow; Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 621.373.826:535.3

[Abstract] A study was made of the problem of applying a model of a "slit" beam for evaluating the level of distortions and the possibilities of their compensation during the blooming of beams with a finite cross-sectional area. Allowance is made for such features of extended atmospheric paths as nonuniformity of the refractive index along the optical axis of the radiation beam, scanning with the radiation beam and the pulse-frequency time mode of radiation source operation. It is shown that a model of a "slit" beam makes it possible to investigate the qualitative features of correction of thermal distortions of laser radiation on inhomogeneous atmospheric paths, which considerably lessens requirements on computer resources ensuring adequate simulation. Scaling factors were obtained which make it possible to evaluate the effectiveness of compensation of distortions for beams when using a two-dimensional aperture on the basis of the results of simulation of beams when using a one-dimensional aperture for extended inhomogeneous atmospheric paths. Figures 3; references 7: 5 Russian, 2 Western.

### Phase Distortions of Optical Beam During Its Blooming Under Gravitational Convection Conditions

917N0110J Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 (manuscript received 1 Oct 90)  
pp 1307-1311

[Article by V. P. Lukin and B. V. Fortes, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 621.378.325:535.3

[Abstract] The process of gravitational convection arising during the heating of gas in an optical beam was investigated. An effective program was developed which makes it possible to compute and to visualize on a display the dynamics of a plane convective current arising during the propagation of a strong beam in a horizontally positioned cell with a square section. The efficiency in use of modal and segmented mirrors for the correction of phase distortions arising during beam propagation through temperature inhomogeneities was evaluated. In contrast to earlier studies, in which the modal composition of such distortions was studied, it was found that with an increase in radiation power the spectrum of phase distortions is displaced in the direction of high-order aberrations. Figures 3; references 13: 11 Russian, 2 Western.

#### Simulation of Wave Front Reversal Correction for Laser Beams in Atmosphere

917N0110K Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1312-1320

[Article by O. I. Vasilyev, Yu. N. Kolomiyets, S. S. Lebedev and L. P. Semenov, Experimental Meteorology Institute, Tayfun Scientific Production Association, Obninsk, Kaluga Oblast]

UDC 621.373.826

[Abstract] Considerable difficulties are involved in research on the possibilities of compensation for atmospheric distortions of laser beams by a wave front reversal mirror. Accordingly, for study of the principal regularities of such adaptive correction it is necessary to use laboratory simulation based on similarity theory. Such laboratory-numerical simulation was used in studying the effectiveness of correction of short pulses in the atmosphere by a wave front reversal mirror. Different conditions for the propagation of a corrected beam in the atmosphere are examined: a) the beam does not experience nonlinear distortions in a turbulent medium; b) the beam experiences induced Raman scattering while propagating in a turbulent medium; c) the distortions of a corrected pulse are caused by the heating of a moving medium as a result of the transmission of uncorrected pulses at a high repetition rate through it. The influence of induced Raman scattering on the quality of retrieval of a corrected beam in a turbulent medium is examined in detail for a number of situations. It is shown that the effectiveness of wave front reversal correction can be considerably limited by the inaccuracy in wave front reversal by a real mirror and nonlinear phenomena transpiring during propagation of corrected waves in the atmosphere. Figures 5; references: 9 Russian.

#### Research on Intensity Fluctuations of Reflected Radiation in Turbulent Atmosphere by Statistical Tests Method

917N0110L Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1321-1324

[Article by P. A. Konyayev, V. P. Lukin, G. Ya. Patrushev and S. Yu. Tabakayev, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 621.378.325

[Abstract] In order to overcome the difficulties encountered in the adaptive correction of turbulent distortions of optical beams it is proposed that a study be made of the statistical properties of optical waves scattered on quite limited reflectors using statistical tests in which the wave propagation process in direct and return directions is simulated by its transmission (with allowance for diffraction) through a set of corresponding phase screens. With the availability of a high-capacity computer such an approach is universal, making possible not only correct allowance for diffraction of an optical wave on a real reflector, but also effective research in the range of values of turbulence parameters inaccessible for analytical computations. A graphic example is given showing the possibilities of the proposed method for study of the specific characteristics of reflected waves in different adaptive and sounding systems in situations very close to real when other computation methods do not yield reliable quantitative results. Figures 4; references 6: 5 Russian, 1 Western.

#### Spatial Filtering in Problems of Wave Front Measurement by Hartmann Method

917N0110M Tomsk *OPTIKA ATMOSFERY* in Russian  
Vol 3 No 12, Dec 90 pp 1328-1330

[Article by A. V. Kurenkov, V. I. Kislov and O. I. Shanin, Scientific Production Association, Luch Scientific Research Institute, Podolsk]

UDC 538.3

[Abstract] The study of various physical processes requires the most precise possible measurement of the wave front. In actuality, the measured wave front differs from the true front due to the nonideality of the measuring instrument and the presence of noise in the wave front (related to such factors as the small-scale component of the wave front in linear adaptive systems used in compensating the low-frequency part of the wave front). An improved transfer function for the measuring instrument is proposed and pertinent relations are derived. A wave front measurement process is described which involves use of a Hartmann transducer in the process of filtering of spatial frequencies. This makes it possible to evaluate the measurement error and optimize the principal parameters of the measuring instrument.

The expressions used for this purpose are cited. The results also can be used in solving problems in wave front retrieval and control. Figures 2; references: 5 Russian.

### Methods for Atmospheric Correction of Data From Remote Optical Measurements

917N0109A Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1139-1153

[Article by I. V. Mishin]

UDC 551.521.535.31:535.36

[Abstract] A classification of atmospheric correction methods is proposed. The best developed methods, whose effectiveness was checked in numerical or in situ experiments, are examined individually. Research on atmospheric correction methods made it possible to formulate the general principles for such constructions and to give recommendations on their improvement. In addition to the development of improved measuring instruments, one of the progressive trends is the introduction of precise solutions of boundary value problems in transfer theory into atmospheric correction algorithms. The pertinent theory makes it possible to define a series of general principles for solving inverse problems. The desirability of use of one method or another is determined by the structure of remote measurement data and the properties of the underlying surface. The use of alternative methods and an increase in the number of measuring channels should increase the reliability in determining the classes of natural features. Since different methods were used under dissimilar atmospheric-optical conditions and with use of different measuring instruments and the results are represented in different form, at present it is impossible to classify the methods by accuracy. One of the timely problems is therefore a study of the atmospheric correction algorithms under identical conditions by the mathematical simulation method. References 79: 51 Russian, 28 Western.

### Amplitude-Time Characteristics of Pulsed Optical Radiation Passing Through Cloud Layer

917N0109B Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1154-1158

[Article by V. A. Korshunov, Tayfun Scientific Production Association, Obninsk]

UDC 551.521.3:535.361

[Abstract] The Monte Carlo method is used in an analysis of the amplitude-time characteristic of pulsed radiation transmitted through a cloud layer as a function of the observation angle and the detector field of view. The case of perpendicular incidence of a broad monodirectional beam is considered. This corresponds to an experiment in which a small source is situated above a cloud layer at an adequate distance from its upper boundary

and the detector is at the Earth's surface. Amplitude-time characteristics are obtained for intensity as a function of the observation angle and power for different reception angles for optical depths of the layer less than or equal to 50. The nature of these dependencies is determined by the presence of two radiation components, small-angle and diffusional, having different time scales and angular dependencies. Figures 4; references 8: 7 Russian, 1 Western.

### Dependence of Amplitude-Time Characteristics of Pulsed Optical Radiation Passing Through Cloudy Medium on Cloud Cover Parameters

917N0109C Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1159-1164

[Article by V. A. Korshunov and L. N. Pavlova, Tayfun Scientific Production Association, Obninsk]

UDC 551.521.3:535.361

[Abstract] The influence exerted on amplitude-time characteristics of pulses passing through a cloudy medium by a number of cloud cover parameters, including the extinction coefficient, probability of absorption of a quantum, scattering phase function and distance from cloud layer to detector, is examined. The computed amplitude-time characteristics for several models of continuous cloud cover of the stratiform type, including multilayer, are given. It is assumed that a source with a small angular divergence is situated at a great distance from the Earth's surface (such as in an earth satellite orbit) and that its optical axis is directed vertically downward. It is shown that the amplitude-time characteristics of pulses transmitted through a cloudy medium are determined primarily by the optical depth of the cloudy medium. With an identical optical depth they are also dependent on the number and altitude of the cloud layers and the values of their extinction coefficients. The variations of the particle-size distribution in real liquid-drop clouds exert no significant influence on the amplitude-time characteristics of the pulsed radiation. Among the different types of cloud cover it is multilayer systems with a high positioning of the layers and low extinction coefficients which cause the maximal pulse broadening. Figures 4; references 10: 8 Russian, 2 Western.

### Developing Engineering Method for Evaluating Atmospheric Transmission

917N0109D Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1165-1168

[Article by V. P. Ivanov, State Applied Optics Institute, Kazan]

UDC [551.521.3:551.510.42].001.572

[Abstract] An engineering method is proposed for the analysis of atmospheric transmission in the spectral

ranges 3-5 and 8-12  $\mu$  which will enable specialists to make similar evaluations for a broad class of optoelectronic instruments operating in the intermediate- and far-IR ranges. The sphere of applicability of this method is as follows: 1) atmospheric surface layer (horizontal sighting paths), 2) Atlantic- continental European climatic region of USSR; 3) weather conditions characterized by an air temperature  $T = -12^\circ$  in the absence of hydro- or lithometeors. A wide-band atmospheric transmission function is selected as an integral index characterizing transmission in the spectral range  $\Delta\lambda = \lambda_2 - \lambda_1$ . The proposed method for the analysis of atmospheric transparency in the IR range is convenient for engineering evaluations and is recommended for use in an in situ experiment because the only input parameters in the method are data from standard meteorological observations. A table gives estimates of the relative error in determining the atmospheric transmission function for different meteorological ranges of visibility on paths with an extent  $R = 1$  km. The main contribution to the error in estimating atmospheric transparency is from errors in registry of the meteorological range of visibility using standard meteorological instruments. Figure 1; references: 9 Russian.

#### Influence of Scattering in Rain on Optical Image Fluctuations

917N0109E Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1169-1175

[Article by I. P. Lukin and B. N. Chen, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 534.222

[Abstract] The results of theoretical research on random displacements of images of a light beam passing through a layer of the turbulent atmosphere during the falling of precipitation are presented. Computations of image dispersion were made using a solution of an equation for the coherence function for a fourth-order field by the perturbations method. The conditions are found under which the contribution of atmospheric precipitation to fluctuations of displacement of the center of gravity of an optical beam image exceeds the contribution of atmospheric turbulence. The presented materials indicate the importance of the influence of precipitation (rain) on infrared radiation for virtually any size of the receiving apertures, but only with small apertures for optical radiation in the visible range. The relations derived in the study make it possible to propose new methods for remote measurements of the optical characteristics of atmospheric turbulence and precipitation. Such methods include the reception of a light beam simultaneously in two apertures (large and small) or two optical waves with different wavelengths in one aperture, making it possible to measure the mean concentration of rain droplets and the structural parameter of fluctuations

of air permittivity during the falling of precipitation. References 14: 12 Russian, 2 Western.

#### Analytical Formula for Retrieving Phase From Light Field Intensity

917N0109F Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1200-1204

[Article by V. P. Aksenov, Atmospheric Optics Institute, Siberian Department, USSR Academy of Sciences, Tomsk]

UDC 535.12

[Abstract] The problem of wave front retrieval from intensity distributions is known as the phase problem in optics. This problem is usually solved by iteration methods, but there are other variants of a solution. T. V. Kuznetsova (KVANTOVAYA ELEKTRONIKA, Vol 15, No 9, pp 1921-1922, 1988), for example, derived a formula for retrieving the Wigner function in which the intensity distribution in an infinitely extended medium is used. This approach, using excessive information for determining wave phase, is nonoptimal and a method is needed for decreasing the volume of data necessary for retrieval purposes. Moreover, the information on phase latent in the Wigner function is inconvenient for analysis and comparison of different retrieval algorithms. In this article, on the basis of the correlation between the projection of the Wigner function and the intensity of the wave field established by Kuznetsova an analytical formula is found for phase retrieval. The derivation is for a field with a dependence on one transverse coordinate. This formula expresses the phase profile of a two-dimensional light field through the distribution of its intensity for a monochromatic coherent light beam on the basis of a Radon transform of generalized functions. References: 4 Russian, 1 Western.

#### Accuracy of Doppler Method in Radioacoustic Sounding of Atmosphere in Short-Wave Radio Range

917N0109G Tomsk OPTIKA ATMOSFERY in Russian  
Vol 3 No 11, Nov 90 pp 1205-1209

[Article by V. G. Gavrilko and A. A. Semerikov, Gorkiy State University imeni N. I. Lobachevskiy]

UDC 551.501.724:551.596

[Abstract] Until recently it was assumed that the radioacoustic sounding method could be used only to altitudes about 1-3 km, but there has been broad discussion of the possibilities of stratospheric- tropospheric systems. Y. Masuda (RADIO SCIENCE, Vol 23, No 4, p 647, 1988), among others, demonstrated that the method is applicable to altitudes 15-20 km. It appears that this requires a changeover to the short-wave radio range with an adequately great power of both the acoustic and electromagnetic radiations used and with compensation for

wind drift. An expression is derived for the power spectrum of the received signal at the point of wind drift compensation with allowance for atmospheric turbulence during the scattering of a series of electromagnetic pulses on an individual sound pulse. In order to achieve the desired accuracy in measuring temperature it will be necessary to construct antennas with narrow directional diagrams in a wavelength range about 10 m. References: 7 Russian.

**Physical Principles of Space Monitoring of Water Bodies in Visible and Near-IR Spectral Zones**

*917N0081A Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 6, Nov-Dec 90 (manuscript received 26 Jun 89) pp 44-48*

[Article by K. Ya. Kondratyev and F. T. Shumakov, Limnology Institute, USSR Academy of Sciences, Leningrad; All-Union Scientific Research Institute for Water Management Problems, Moscow]

UDC 551.464:629.78

[Abstract] A detailed study was made to clarify what space images could be best used in a future global space system for ecological monitoring of the hydrosphere. Space images obtained in the spectral range 0.46-0.60 $\mu$ m must be used in the remote determination of high relative transparencies ( $>5$  m), low concentrations of chlorophyll a ( $<1.5$   $\mu$ g/liter) and suspended matter ( $<1$  mg/liter), trophic state of ultraoligotrophic and oligotrophic lakes, dystrophic water bodies and river waters with high color indices, depth and mapping of zones of occurrence of submerged higher aqueous vegetation. On the other hand, multiband space images in the range 0.6-0.7 $\mu$ m can be effectively used in remote evaluation of relative transparency in the interval 2-5 m, concentrations of chlorophyll a in the range 1.5-10 $\mu$ g/liter and suspended matter in the range 1-10 mg/liter, trophic state of mesotrophic water bodies and expanses of zones of entry and propagation of waste waters. Space survey materials obtained in the near-IR spectral zone in the range 0.7-1.1 $\mu$ m must be used in determining relative transparencies  $<2$  m, chlorophyll a content  $>10\mu$ g/liter, trophic state of eutrophic and hypereutrophic water bodies and morphometric parameters of water bodies. Reflection from the bottom and the presence of dissolved organic matter in any concentrations exert no influence on the characteristics of water bodies registered on images in this range. Space photoinformation obtained in the spectral range 0.46-0.7 $\mu$ m, with allowance for the angular characteristics of diffuse reflection, can be used in determining the type of suspended organic and inorganic matter in water bodies. References 11: 10 Russian, 1 Western.

**Retrieval of Spatial Spectra of Sea Surface From Optical Images in Nonlinear Model of Brightness Field**

*917N0081B Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 6, Nov-Dec 90 pp 60-70*

[Article by A. B. Murynin]

UDC 551.466.326:528.77

[Abstract] Until now the problem of retrieving sea surface spectra from optical images has been solved on the assumption of a linear dependence between slopes of surface elements and their brightness. However, deviation of this dependence from linear, occurring under real conditions, results in considerable distortions of evaluations of the spectra of sea surface slopes. In order to reduce these distortions a number of recommendations have been made on the choice of the geometry of sighting during image registry, but such recommendations by no means can always be satisfied in the course of real aerospace experiments. Methods for correcting nonlinear distortions of the spectra of sea surface slopes under arbitrary illumination conditions have been developed inadequately and existing analytical evaluations of nonlinear distortions have only an extremely limited field of applicability. It is therefore essential to have procedures for correcting these nonlinear distortions when retrieving sea surface spectra from optical images. A method is proposed for filling this gap. It involves numerical simulation of optical images and computation of nonlinear distortions by a comparison of the spectra of slopes and surface brightness. The described method makes it possible to eliminate nonlinear distortions of wave spectra having different physical origin. The nonlinear distortions of wave spectra are evaluated for different image formation conditions. The outlined procedures and proposed formulas will be useful in reliable research on wind wave development, on the interaction between internal and surface waves and in ascertaining the degree of pollution of the sea surface by petroleum products. Figures 2; references 14: 8 Russian, 6 Western.

**Radiometric Determination of Dynamics of Temperature, Heat Flow and Parameters of Earth's Surface on Basis of Solution of Thermal Evolution Equations**

*917N0081C Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 6, Nov-Dec 90 pp 71-78*

[Article by K. P. Gaykovich, Gorkiy Radio Physics Scientific Research Institute]

UDC 528.811

[Abstract] A study was made of shortcomings in determining the dynamics of temperature of the Earth's surface and flow through the surface, ground parameters and the method for retrieving the soil moisture content profile. It is shown that on the basis of joint solution of

the radiation transfer and thermal conductivity equations thermal evolution equations can be derived which relate the observable brightness temperatures and the preceding evolution of surface temperature or the evolution of the heat flow through the surface. Methods were developed and experimentally tested: a) for determining the dynamics of the surface temperature (heat flow) and subsurface temperature profile of a half-space on the basis of single-wave measurements of the time dependence  $T_{br}(t)$ ; b) retrieval of thermal history of surface by measurement of the spectrum  $T_{br(\lambda)}$ . The case of an inhomogeneous medium was examined and a method is proposed for retrieving the deep profile of ground moisture content on the basis of single-wave measurements of  $T_{br}(t)$  and  $T_0(t)$  in the microwave and IR ranges respectively. These methods, based on solution of thermal evolution equations, also are extremely promising for radiometric sensing of the surfaces of other planets and asteroids because due to the absence of moisture the radiation coefficient is close to unity and the temperature variations associated with characteristic rotation and orbital motion are very great. Figures 2; references 20: 17 Russian, 3 Western.

#### Organization of Collection and Processing of Navigational-Geodetic Information on Professor Kurentsov Scientific Research Ship

917N0097A Moscow *IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA* in Russian No 4, Jul-Aug 90 pp 16-21

[Article by D. Ye. Kucherenko, engineer, Sevmorgeologiya Geological Production Association]

UDC 528.2/.3

[Abstract] The organization of an automated shipboard system for the collection and processing of navigational-geodetic information is described and illustrated. The general technical structure of the system is discussed and details on the collection, storage and processing of data on a shipboard computer are presented. The practical geodetic programs employed in conjunction with the system are concisely described. This system was developed on the Professor Kurentsov research ship and is now in operation aboard that vessel. The advantages of the system are as follows. Registry is on relatively inexpensive and small equipment which can be placed near navigation instruments. The hydrographer is thereby able to monitor the registry process and control it and there is no need for keeping an operator at the computer center who must insert a magnetic tape, constantly check its normal operation, introduce data and clear up malfunctions. System operation is not dependent on computer breakdowns, increasing system reliability as a whole. Data can be processed later at any time convenient for hydrographers and computer center personnel with reduction of costly computer time to a minimum. One of the principal merits of this system is

that all the information prior to processing is subjected to editing and checking, reducing the probability of appearance of errors. The rate of processing and transmission of data is increased and the percentage of manual office work is reduced. Fig. 1.

#### Theory of Stereophotogrammetric Survey of Moving Objects From One Image Center

917N0097B Moscow *IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA* in Russian No 4, Jul-Aug 90 pp 65-69

[Article by Ye. I. Kalantarov, docent, candidate of technical sciences, and V. I. Nefedov, docent, candidate of technical sciences, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers, and I. I. Menukhov, candidate of technical sciences, Scientific Research and Planning-Design Institute for Prefabricated Modular Construction, Tyumen]

UDC 528.718

[Abstract] At the present time in the determination of deformations of different large structural components in the course of their transport it is common to use a surface stereophotogrammetric survey. In this article other methods are proposed for obtaining stereoscopic photographs of moving objects. A detailed derivation of the principal mathematical equations is given; these make it possible to determine the spatial coordinates of points on the object and then use the coordinates to compute deformation of such structural components in the course of their transport. The theory of three analytical methods for obtaining stereopairs of moving objects from one image center is examined: by linear displacement of the surveyed object by  $R_0$  without changing its angular orientation in space; by changing the angular orientation of the surveyed object or camera; by a change which includes both the linear and angular orientation of the surveyed object. The results of experimental work using real photographs are cited which confirm the validity of the theory of the proposed methods for the processing of stereopairs obtained from one image center. Figure 1; references: 2 Russian.

#### Optimizing Illumination in Choice of Relative Positioning of Light Source and Survey Camera

917N0097C Moscow *IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA* in Russian No 4, Jul-Aug 90 pp 70-75

[Article by Yu. L. Biryukov, docent, candidate of technical sciences, and L. A. Saykova, senior instructor, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers]

UDC 528.711.11-771.319.55

[Abstract] The problem of optimizing illumination in the neighborhood of a photographed object is examined. The requirement on maximizing illumination at a point where an object of minimal height is situated, which can be detected from its shadow on an image, leads to a definite positioning of the light source and survey camera relative to the object. Such a relative positioning of the survey camera, light source and an object with stipulated properties can be found from any two parameters characterizing their position at the time of a survey. Formulas are derived which can be used in determining the optimal relative positionings. Examples are given which show that if the light source and survey camera are displaced by 20-30 percent from the optimal position the illumination of the object is reduced by 50-60 percent, whereas a displacement by a factor of 2-3 reduces illumination by 85-99 percent. Figure 1; reference: 1 Russian.

#### Theoretical Validation of Requirements on Stabilization of Carrier of Scanner Remote Sensing Survey System

917N0097D Moscow *IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA* in Russian No 4, Jul-Aug 90 pp 81-84

[Article by A. P. Mikhaylov, docent, candidate of technical sciences, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers]

UDC 528.711.4

[Abstract] The requirements on stabilization of the carrier of a scanner remote sensing survey system are validated. These ensure obtaining a high-quality image which represents the totality of the individual line images obtained by central projection from different photographic points. Since charge-coupled instruments in most cases are used as the radiation detectors in the optoelectronic systems employed in such surveys the formulas derived in the article are directed to solution of such problems as avoiding gaps between images in adjacent lines or the superposition of lines on one another. The conditions for efficient positioning and operation of the charge-coupled instruments are examined. A method for computing the admissible levels of change in the elements of outer orientation of the scanner survey system and the admissible rates of their change during the course of a survey is outlined. References: 2 Russian.

#### Joint Processing of Overlapping Photographs and Radar Images

917N0097E Moscow *IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA* in Russian No 4, Jul-Aug 90 (manuscript received 27 Jul 89) pp 95-99

[Article by V. G. Yelyushkin, candidate of technical sciences, and Yu. Ye. Ryazantsev, engineer]

UDC 528.72:528:74

[Abstract] Advances in remote sensing suggest the possibility of replacing the traditional approaches used in the joint processing of photographs and radar images which were based on use of common control points on the photographs and radar images and solution of the inverse photogrammetric problem. The theory of a new method for determining the coordinates of terrain points and the angular orientation of a photograph by means of the joint processing of overlapping photographs and radar images with use of information obtained by navigation systems is described. The examined method makes possible an appreciable simplification of the problem in comparison with known methods and allows dispensing with use of control points when determining the angular elements of photograph orientation. The formulas necessary for this purpose are given. The use of this method will favor the broader practical introduction of modern phototopographic application of terrain data obtained using survey systems of different types. Figure 1; references 5: 2 Russian, 3 Western.

#### Influence of Photomaterial Noise on Informational Properties of Color Aerial Photographs

917N0097F Moscow *IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: GEODEZIYA I AEROFOTOSYEMKA* in Russian No 4, Jul-Aug 90 pp 122-126

[Article by O. N. Syedin, Moscow Order of Lenin Institute of Geodetic, Aerial Mapping and Cartographic Engineers]

UDC 528.7

[Abstract] Research is being carried out to resolve contradictory information in the literature on the information capacities of color and black-and-white images. This work includes a microdensitometric analysis of color aerial images with subsequent input of pertinent data into a computer and statistical processing. Preliminary information on the influence of color on the information capacity of aerial photographs obtained in this research, in which the signal-to-noise concept is applied, is examined. The definite advantages of color and false-color photographs in comparison with black-and-white images are discussed. Since the structure of a uniformly exposed and developed photographic layer is directly related to the range of granularity of the photographic material (the form of the granularity spectrum is different for different color films, but also for the very same film) it is emphasized that these granularity spectra must be taken into account in evaluations of the quality of color and false-color images. Information capacity cannot be properly determined without allowance for this important factor. References 5: 4 Russian, 1 Western.

**Pollution of Black Sea Called Catastrophic**  
917N0086A Moscow RABOCHAYA TRIBUNA  
in Russian 6 Mar 91 pp 3-4

[Article by Mikhail Dmitruk based on round-table discussion in RABOCHAYA TRIBUNA office, date not specified, under the rubric "Second Warning"; first two paragraphs are an introduction]

[Text] Can the Black Sea catch fire? This question was raised for the first time in an article by M. Dmitruk entitled "Energy of the Sea Depths" (SOTSIALISTICHESKAYA INDUSTRIYA, 26 April 1989). That article contained information which earlier had been kept secret. In the opinion of some scientists, the hydrogen sulfide pollution of the Black Sea has assumed a catastrophic character and threatens death to an enormous region.

But the situation is not hopeless: the catastrophe can be averted if the excess of fuel gas can be removed from the sea. Scientists have proposed that this be done using an electric power station which will operate on hydrogen sulfide extracted from the deep waters. Sulfur will be produced as a byproduct.

Two years have passed since then. During that time it has been possible to solve many of the problems raised by scientists. But what of a practical nature has been done? This was discussed by the participants in a "round table" held at RABOCHAYA TRIBUNA. Leading specialists on the hydrogen sulfide problem gathered for this event.

Rustam Akhmedov, doctor of technical sciences, winner of the State Prize and the Prize of the USSR Council of Ministers, general director of the Ekoenergetika State Interbranch Scientific Production Association; Boris Vasilyev, doctor of technical sciences, head of the sulfuric acid problems laboratory of the Scientific Research Institute for Fertilizers, Insecticides and Fungicides; Petr Zaytsev, doctor of chemical sciences, head of the analysis laboratory of the Scientific Research Institute for Fertilizers, Insecticides and Fungicides; Viktor Klimenko, candidate of chemical sciences, docent in the Chemistry Department of the Moscow Automobile-Highway Institute.

Journalists from areas around the Black Sea and colleagues from the central newspapers and agencies arrived. The meeting was chaired by Viktor Andriyanov, first deputy chief editor of the newspaper RABOCHAYA TRIBUNA.

[R. Akhmedov] There are many opinions, sometimes incompetent, concerning the Black Sea problem. Here is a typical example. One author declared that the Black Sea...would be turned upside down if we constructed a hydrogen sulfide electric power station there. He says that by raising water from the bottom and returning it to the depths we would risk mixing the upper and lower

layers and as a result poison gas would reach the surface. And a catastrophe would occur precisely due to the attempt to avert one.

If he was interested, the author of this material could learn that we have no intentions at all for returning the "worked out" water to the sea floor. Using our technology the return of water would be to a depth of about 100 meters, into the upper part of the hydrogen sulfide layer. The turning of the sea upside down is out of question. But as a result of such publications there can be a turn-around in the conscious thought of readers: they may cease to believe the initiators of the idea which may be the salvation of the Black Sea.

Illiterate and irresponsible statements form an unfavorable public opinion. This interferes with our work.

[Yu. Katsnelson, APN special correspondent] Readers surely ask you: is it necessary to be concerned with rescue of the Black Sea, which possibly may never catch fire?

[R. Akhmedov] You can't bear a grudge against such readers, but their reasonings are similar to the reasonings of a person who sits on a powder keg while assuring himself that it will never blow up. Before discussing our research I will recall the sorrowful lessons of history which must not be repeated.

There are reports that hydrogen sulfide has already risen from the depths of the Black Sea and was ignited in the air during the great Crimean earthquake of 1927. At that time coastal dwellers in many places saw above the sea grandiose flares of fire with a height up to 500 m and a width of several kilometers. And a strong odor of hydrogen sulfide was sensed on the shore.

According to data from a radiocarbon analysis, after this earthquake the dead zone of the Black Sea began to expand vigorously. Sixty years ago it was separated from the surface about 300 m, but now—120-130 m. And now no one can guarantee that at the time of the next earthquake with an epicenter in the Black Sea the hydrogen sulfide will not reach the surface in a far greater quantity than, evidently, in 1927. What might be the consequences of this outbreak? An answer is suggested by a similar case which occurred several years ago in the African Lake Nios. An enormous quantity of carbon dioxide was dissolved in the near-bottom water layer. And once during a small earthquake it vigorously rose to the surface. A gas cloud covered the neighborhood and about 2000 persons suffocated.

Later research was carried out in this lake and provided a key to solution of the ecological problem. Scientists lowered a rubber hose to the bottom of Nios and began to pump out the water. But after several minutes it rose upward by itself and became a fountain, like champagne from an open bottle. This artificial eruption continued for many hours until the scientists themselves stopped it. If such operations were carried out regularly the carbon

dioxide content in the deep waters would be reduced to a safe level and a catastrophe would not be repeated.

But the Black Sea, to be sure, is incomparably larger than Lake Nios and the gas reserves in it are immeasurably greater. This is not the carbon dioxide which we drink in soda water and exhale from our lungs, but exceedingly poisonous hydrogen sulfide. It is heavier than air. It spreads over the water and land. Even a small quantity of hydrogen sulfide is capable of causing an agonizing death of people and animals. It is difficult to visualize the scale of the catastrophe which the vigorous escape of Black Sea hydrogen sulfide into the atmosphere could cause. In contrast to carbon dioxide it is capable of self-ignition and its ignition point is the same as for the best varieties of fuel.... Several years ago we studied this problem and with utmost seriousness say that the escape and self-ignition of hydrogen sulfide in the Black Sea region are entirely possible.

But there is a real solution for this problem. The high heating power of hydrogen sulfide makes its use advantageous in power production. It can yield cheap electricity and heat. Earlier it was economically disadvantageous to raise the hydrogen sulfide-rich deep waters of the Black Sea. But we have developed a fundamentally new pumping system which makes this process a hundred times cheaper than it was before. This development work is covered by several Author's Certificates which have already been officially registered. We have many other inventions for hydrogen sulfide power production. But on all the Author's Certificates there are handstamps forbidding publication in the open press. As a law-abiding citizen of my country I cannot tell about them to a broad circle of readers in detail, that is, I cannot go beyond the framework of the first two popular science articles about our work. Accordingly, I did not want to speak out for publication.

But some scientists and journalists regarded my silence as a sign of agreement with their notions. With enthusiasm they continued to publish their pseudorefutations, leading readers into confusion.

[Aleksandr Spiridonov, editor of the science section of the newspaper DELOVOY MIR] I recommend that those who assure us that there is no alternative to atomic energy give heed to this. Here it is. Hydrogen sulfide stations could have a power of millions of kilowatts. By using the proposed technologies it would be possible to do away with the Crimean Nuclear Power Plant.

[R. Akhmedov] There are people who understand this. Our development work has been scrupulously studied by two very competent commissions of the State Committee for Science and Technology and the USSR Academy of Sciences. About 150 leading specialists on a variety of problems related to Black Sea hydrogen sulfide participated in these studies. And both commissions came to the unanimous conclusion that the research which we did is promising and must be continued. This enabled the USSR Council of Ministers in 1985 to issue

an order mandating the USSR Ministry of Power and Electrification, in collaboration with concerned ministries and departments, to proceed to the construction in the Black Sea of an experimental plant using hydrogen sulfide from abyssal waters. A similar mission was given to the State Committee for Science and Technology in 1989. But until now nothing has been done for implementing the government decisions.

[Rayna Bycharova, special correspondent of the Bulgarian newspaper ZEMEDELSKO ZNAME in Moscow] What seems to be the holdup?

[R. Akhmedov] For several years we have been carrying out research relying on public support. The government has not spent one kopeck on this work. But the carrying out of large-scale experiments involves expenditures which are beyond our means. The directors of the Ministry of Power and Electrification say that the responsibilities of the ministry do not include the production of sulfur and other raw materials, which it is proposed be obtained from our electric power station; this, they say, is the responsibility of the Ministry of the Chemical Industry. And its directors say that the responsibilities of their ministry do not include the production of electric power at an enterprise for the extraction of sulfur and they kick us over to the Ministry of Power and Electrification. Such a game has been continuing for several years.

[P. Zaytsev] However strange it may seem at first glance, the rescuing of the Black Sea may not be ruinous, but advantageous for our country and for others. The fact is that sulfur is a raw material in very short supply. It is used for the most part in the production of sulfuric acid which is used widely in many branches of industry. Sulfuric acid occupies first place among chemical industry products with respect to scales of production and diversity of fields of use.

But in the territory of the Soviet Union sulfur deposits have been exploited for a very long time and some of them are almost depleted. And new deposits have not been discovered. Accordingly, we ourselves cannot satisfy our needs and we purchase from abroad one million tons of sulfur annually. But the need is constantly increasing. Even now the country is annually using several million tons of sulfur. And when our mines are exhausted will it be necessary to increase our purchases from abroad?

The annual increment of sulfur in the Black Sea is 50 million tons. If we remove only this excess, we will be able to satisfy the needs of our country and become a very large exporter of sulfur in the world market. Its production can be increased still more by setting the goal of lowering the upper boundary of the hydrogen sulfide layer to a safe level.

[V. Andriyanov] Once again we ask the question: why is this idea moving along with such difficulty?

[R. Akhmedov] In my opinion the reason is simple: the fate of hydrogen sulfide electric power production is in the hands of incompetent persons. When there was a recent discussion of the problem of financing this program at the State Committee for Science and Technology the decisive word was spoken by a venerable scientist who long ago demonstrated that hydrogen sulfide cannot burn. And those at the meeting agreed with him. This speaks very eloquently of the competence level of other workers in responsible positions who do not know elementary things from an ordinary school chemistry course. On the basis of their decision the financing of our research has again been put off for an indefinite time.

[Question from the auditorium] But where is the guarantee that an accident will not occur at the electric power station as a result of which the gas raised to the surface is ignited?

[R. Akhmedov] This is precluded in a number of ways. The entire system which holds the hydrogen sulfide is tightly sealed and isolated from the environment. A low pressure, close to atmospheric, is maintained in the entire system. And most importantly, with the slightest irregularity it is sufficient to cut off the pump for delivery of water from the depths so that the entry of hydrogen sulfide into the system will cease. This is all the more true if the pump itself malfunctions.

Ecologically pure sulfur and electric power—this is by far from everything which can be obtained at such a station, which will operate using waste-free technology, without expelling harmful substances into the environment. The deep waters of the Black Sea are very rich in many useful substances: ammonia, manganese, rare-earth elements. It is not surprising that foreign companies are asking us to sell water raised from the bottom at the price of oil. And it is a shame to answer that for several years we will not even begin construction of an experimental plant.

Personally I am ready on my own responsibility and at my own risk to organize a scientific research expedition in the Black Sea this year, even if I do not receive permission, much less financial support.

[B. Vasilyev]. As a specialist in this field I can say that the technology for the processing of hydrogen sulfide into sulfur and sulfuric acid has been well developed. Large plants are operating by this technology both in the USSR and abroad.

During the past year samples of deep waters of the Black Sea, taken from depths of 1 ½ to 2 km, have been analyzed in our laboratory. The analyses confirmed the presence of hydrogen sulfide, up to ten milligrams per liter, as indicated in a number of articles published earlier.

But in order to determine the optimal variant of use of hydrogen sulfide it is necessary to carry out laboratory and experimental studies in the immediate neighborhood of the Black Sea. This requires the organization of

a laboratory there which would be used in testing apparatus for debugging the processes of extraction of hydrogen sulfide from water raised from the depths. On the basis of the results of this research it will be possible to determine the technical-economic characteristics of different processes based on use of Black Sea hydrogen sulfide.

In order for all this to become possible there is an immediate need for finding financing and proceeding at once to the organization of laboratory research. And endless arguments about this will not solve the problem.

[V. Klimenko] I see this problem far more broadly. Indeed, plants for the purification of deep waters do not require electrical power from the outside. It can be obtained rather inexpensively by using hydrogen sulfide. It is desirable that part of this energy be used for the further purification of water from impurities which are in short supply, as has already been mentioned by Rustam Berovich. As a result we would obtain a very great volume of fresh water, which is in such short supply in the Crimea and other regions near the Black Sea. Whereas only toxic substances, salts of heavy metals, would be extracted from the deep waters, in the remaining waters there would be very many nutrients for plankton, algae, crustaceans and fish, which could be "cultivated" in sea farms. This side-industry could be carried on alongside a station. It would serve as an indicator of the ecological purity of production of electric power, sulfur and other raw materials. Now it is even difficult to visualize all the advantages which can be realized from a hydrogen sulfide industry and electric power production, under one condition: that they have good owners and managers. And for the time being, alas, there are none.

[V. Andrianov] We hope that they will in fact be found in our country, and not abroad. RABOCHAYA TRIBUNA will keep an eye on this matter and intends to report to readers how it will be solved.

We hope for the support of the Ministry of Power and Electrification, the Ministry of the Petroleum Refining and Petrochemical Industry and the State Committee for Science and Technology, which still earlier were assigned missions by the government.

[A. Spiridonov] From our conversation readers should not get the impression that the next technocratic storm is in preparation. Both yesterday and today the position of Professor Akhmedov is unchanged: first it is necessary to carry out research, obtain reliable, rechecked experimental data. And only thereafter is it possible to discuss the engineering solution of the problem. There must be a joint discussion between specialists and the public. I hope that it takes place when the necessary research has been carried out.

[R. Akhmedov] The time has come to carry out a whole series of experimental investigations using a specially equipped ship on which it would be possible to refine the data necessary for designing experimental industrial

plants. Representatives of a whole series of specialized organizations must participate in this work. The expenditures in this stage of the work will be not less than a million rubles. Who will supply them and under what conditions? We hope to obtain specific proposals after publication of materials from this "round table." [The article is accompanied by a sketch map showing, for the first time, where the ignition of hydrogen sulfide was observed during the earthquake of 1927 and a diagram representing the rising of the upper boundary of the hydrogen sulfide zone during the last 7000 years (based on radiocarbon research).]

### Precipitation Acidity in Baykal Region

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GIDROLOGIYA in Russian No 1, Jan 91 pp 55-60

[Article by V. A. Obolkin, T. V. Khodzher, Yu. A. Anokhin and T. A. Prokhorova, Environment and Climate Monitoring Laboratory]

UDC 504.064.37.054:551.577.13(282.256.341)

[Abstract] A study was made of the spatial and temporal dynamics of the pH of the snow cover and rain in the

neighborhood of Lake Baykal. Snow samples were collected by helicopter over the course of four-six days and were transported in unthawed form in polyethylene bags to the laboratory; pH was determined immediately upon thawing, together with filtering of solid substances and further chemical analysis. The processing of rain samples was more complex. Measurements were made during the period 1984-1988. Atmospheric precipitation in the background regions of Baykal is characterized by the maximal acidity (pH 4.8-5.2). In these regions precipitation is most sensitive to acidification due to its low mineralization and low buffer capacity. At industrial centers and large populated places in the region the precipitation pH is from 6 to 8 (a regional distribution map accompanies the text). The greatest acid loads with respect to precipitation of the hydrogen ion are observed in mountainous forested ecosystems of the basin where the annual intensity of  $H^+$  receipt is about  $10 \text{ kg/km}^2$ . Two factors participate in the acidification of precipitation in this region: a constant background (global) atmospheric presence of acidic components resulting in an increase in the acidity of precipitation with a decrease in its mineralization; periodic regional increases in the discharge of sulfur and nitrogen oxides causing a brief increase in the acidity of individual precipitation events. Figures 2; references 11: 6 Russian, 5 Western.

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